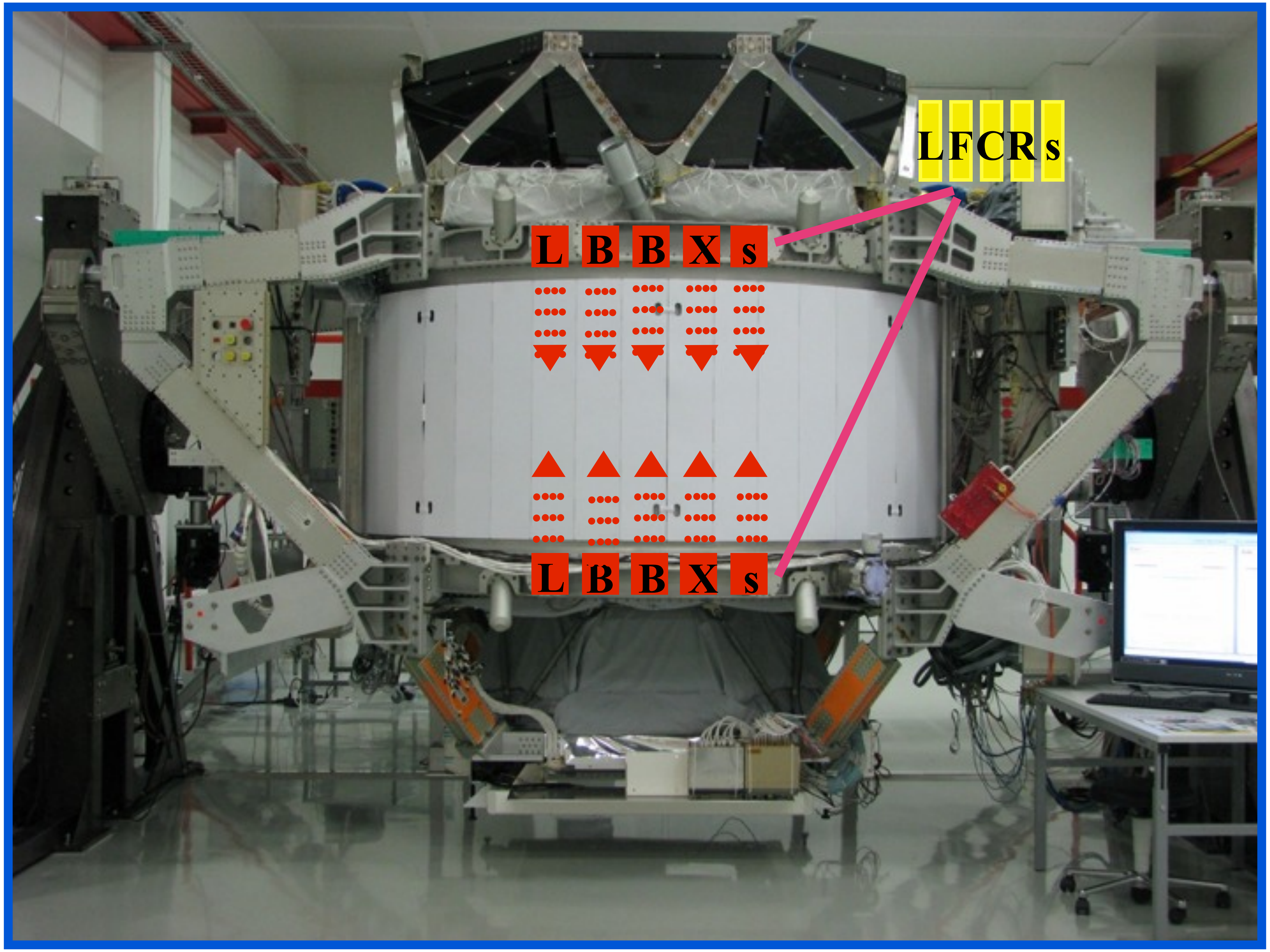
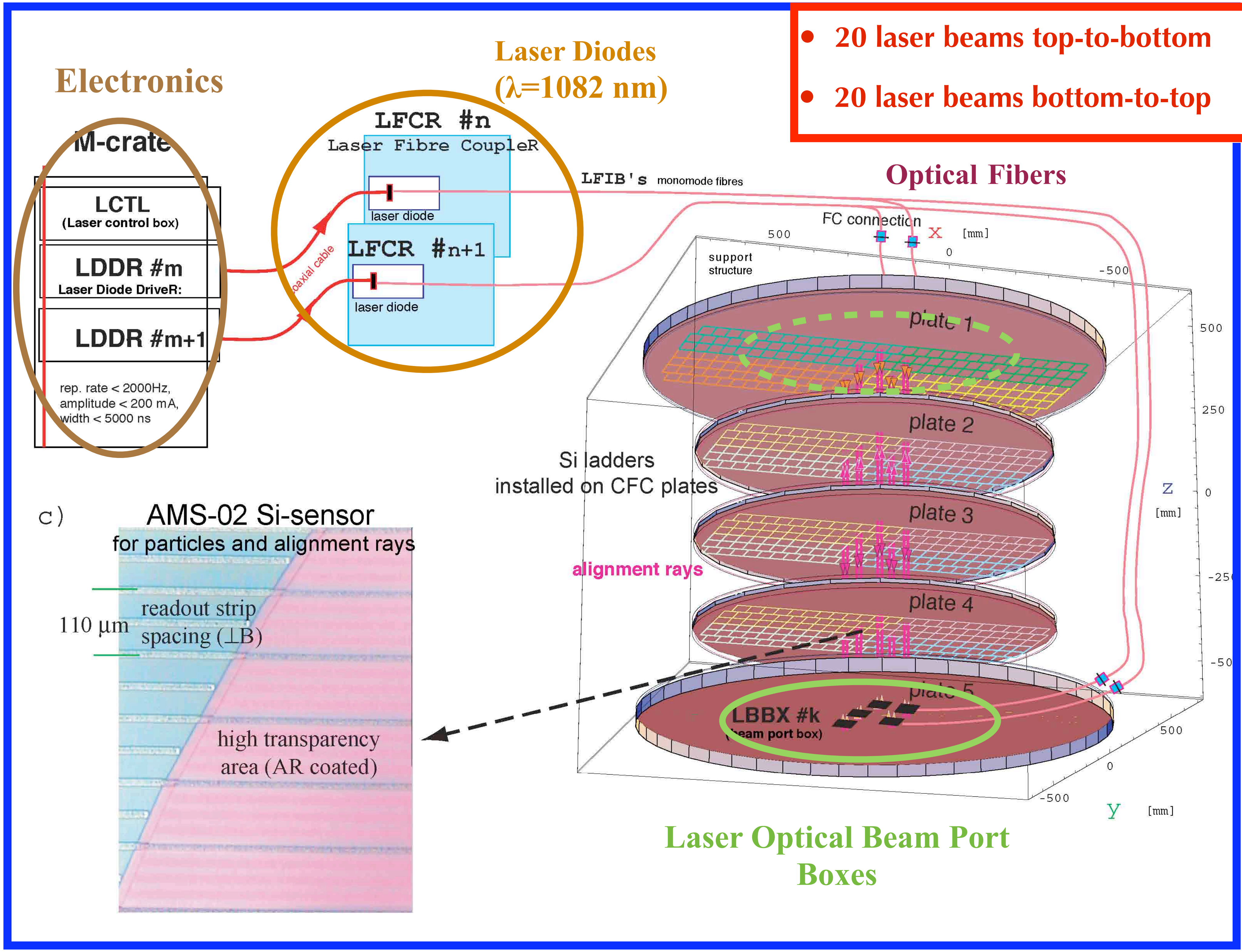
AMS-02 Tracker Alignment System (TAS) ADP

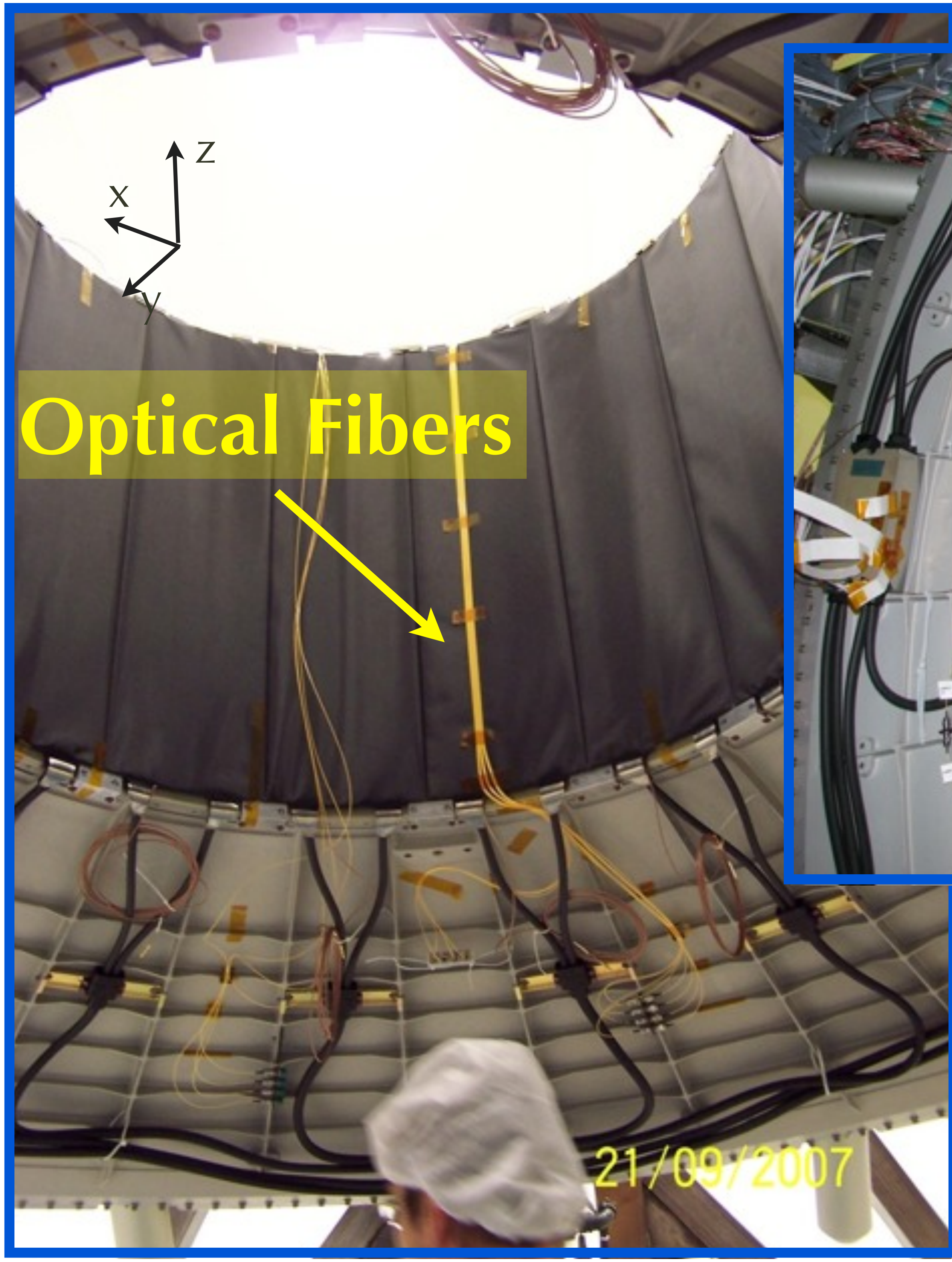


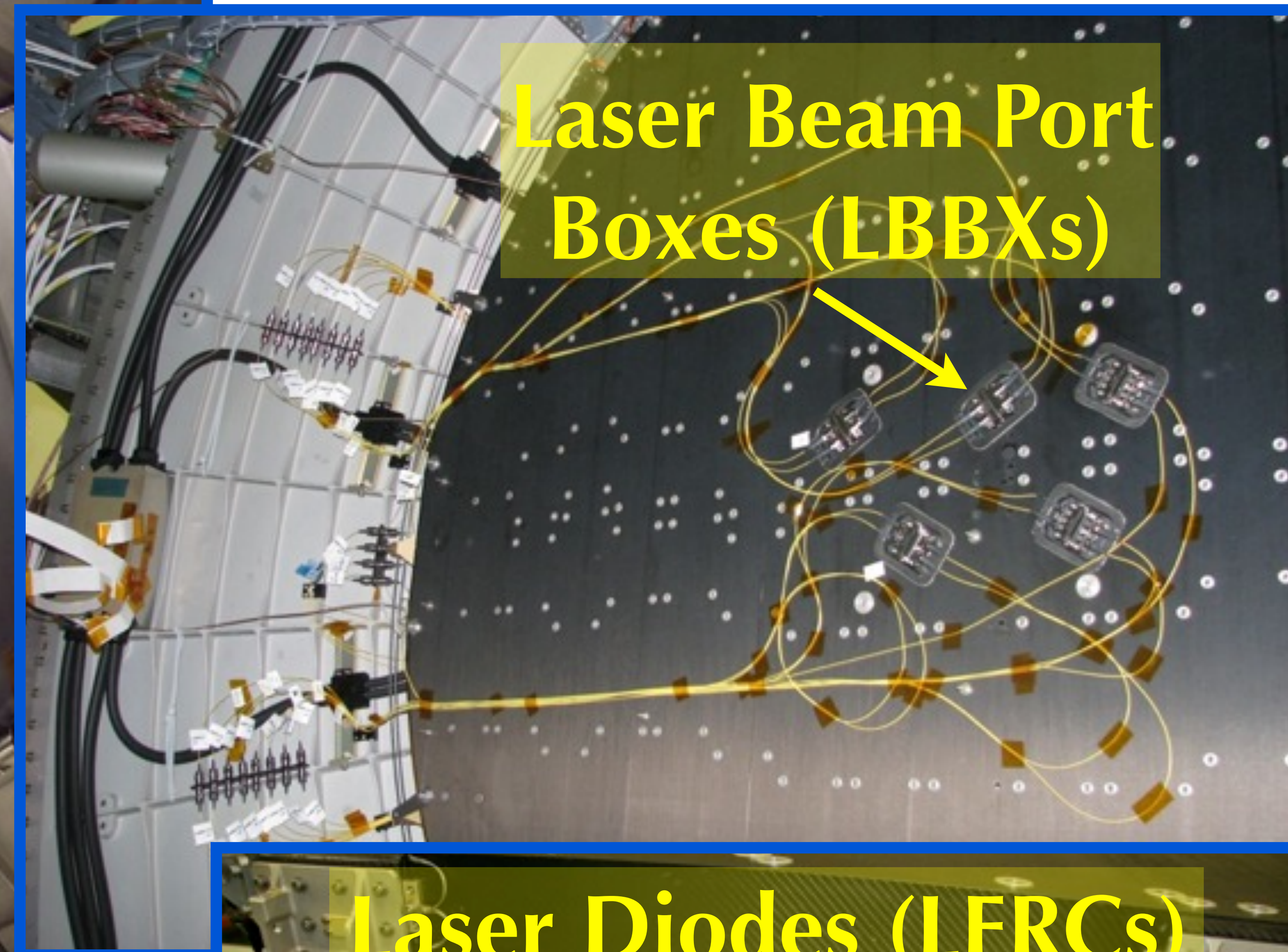
Sonia Natale

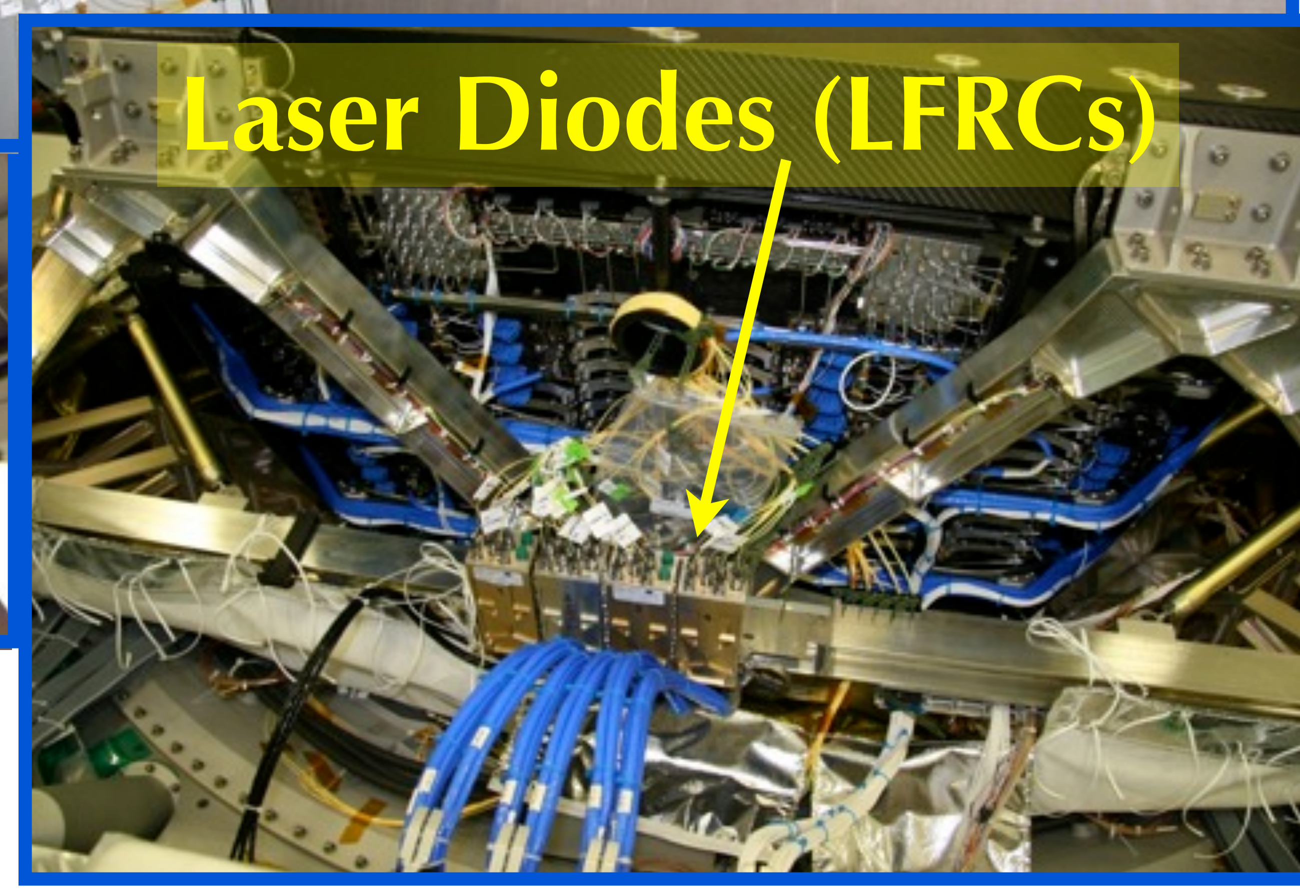
The AMS-02 Tracker Alignment System Layout

- 20 laser beams top-to-bottom
- 20 laser beams bottom-to-top

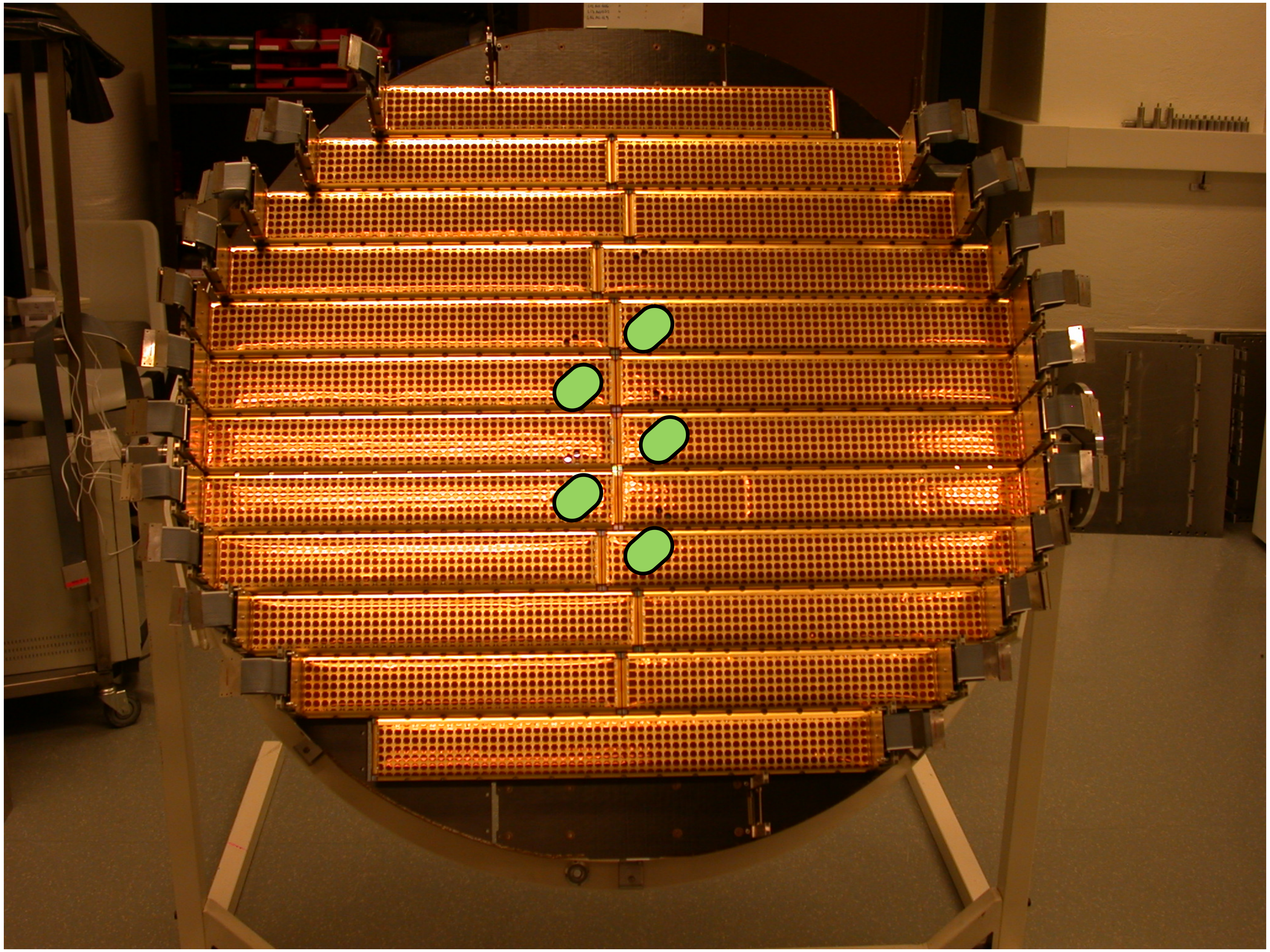



z
x
y
Optical Fibers
21/09/2007


Laser Beam Port
Boxes (LBBXs)


Laser Diodes (LFRCs)

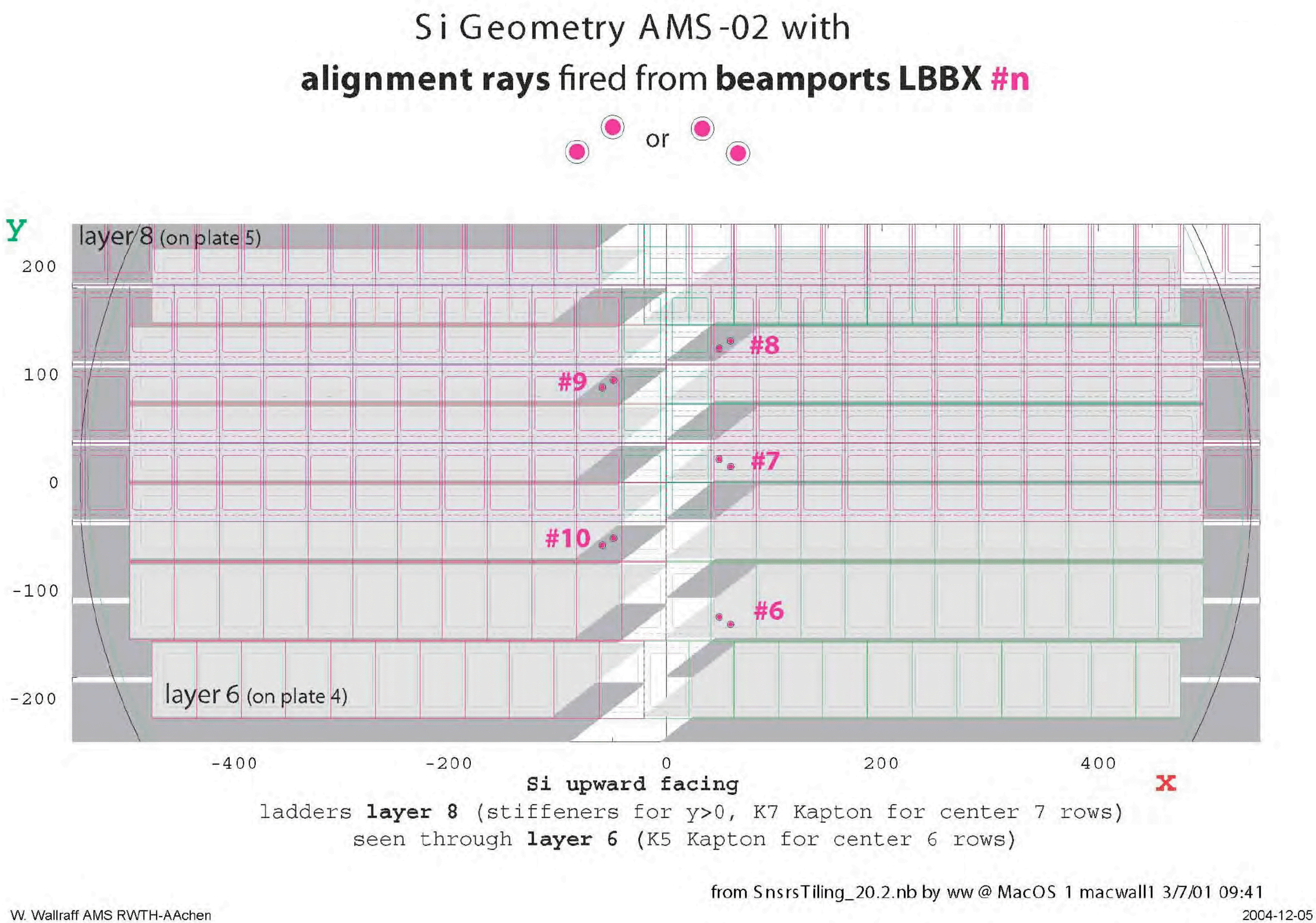
Laser beam access throught silicon ladders



Nominally the laser roads are 6mm wide. So there are approx. 1mm wide margins on either side of the beams.

A substantial effort is needed to fire the laser at the right angle wrt the tracker structure.

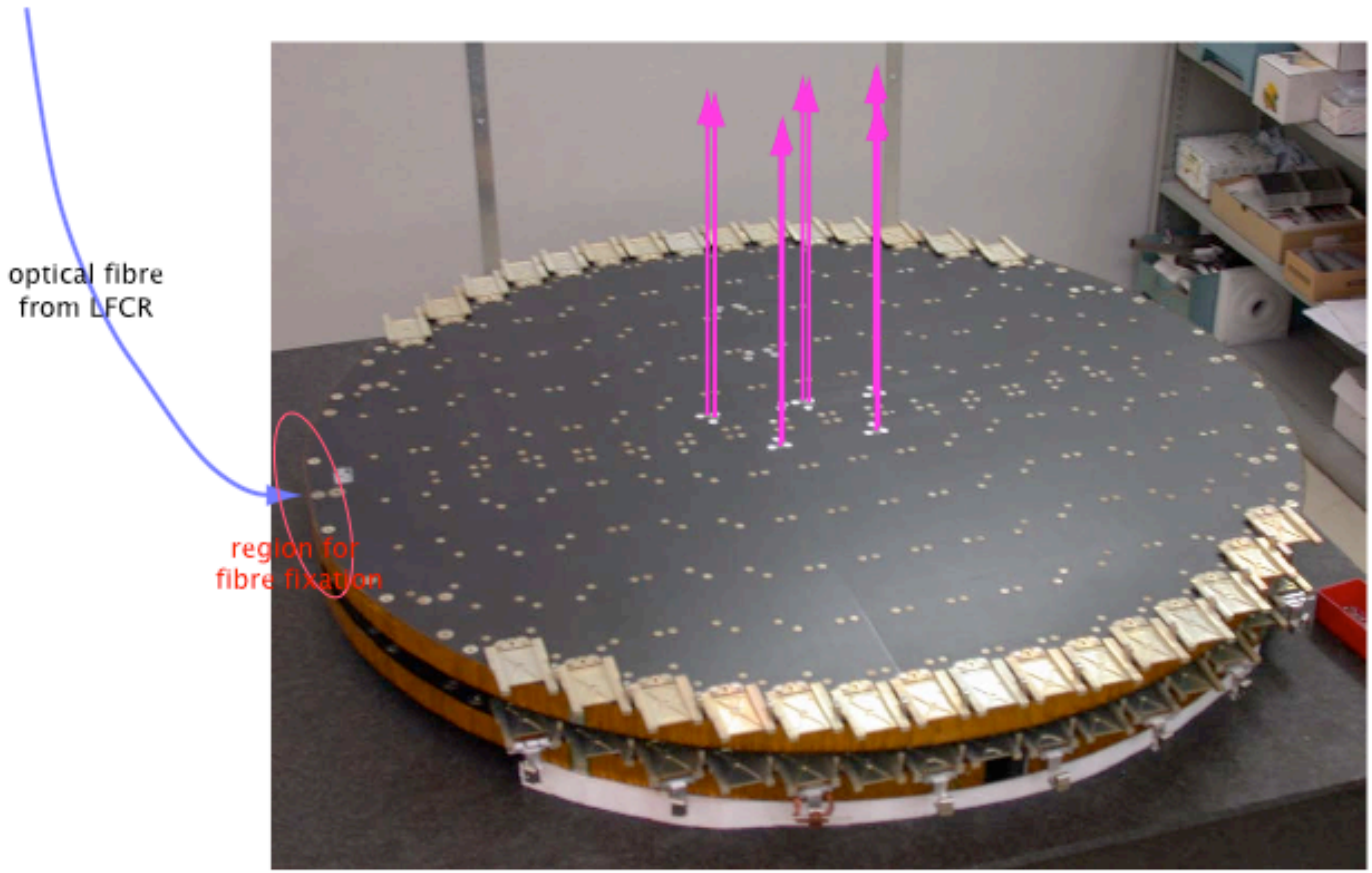
Laser beam access throught silicon ladders



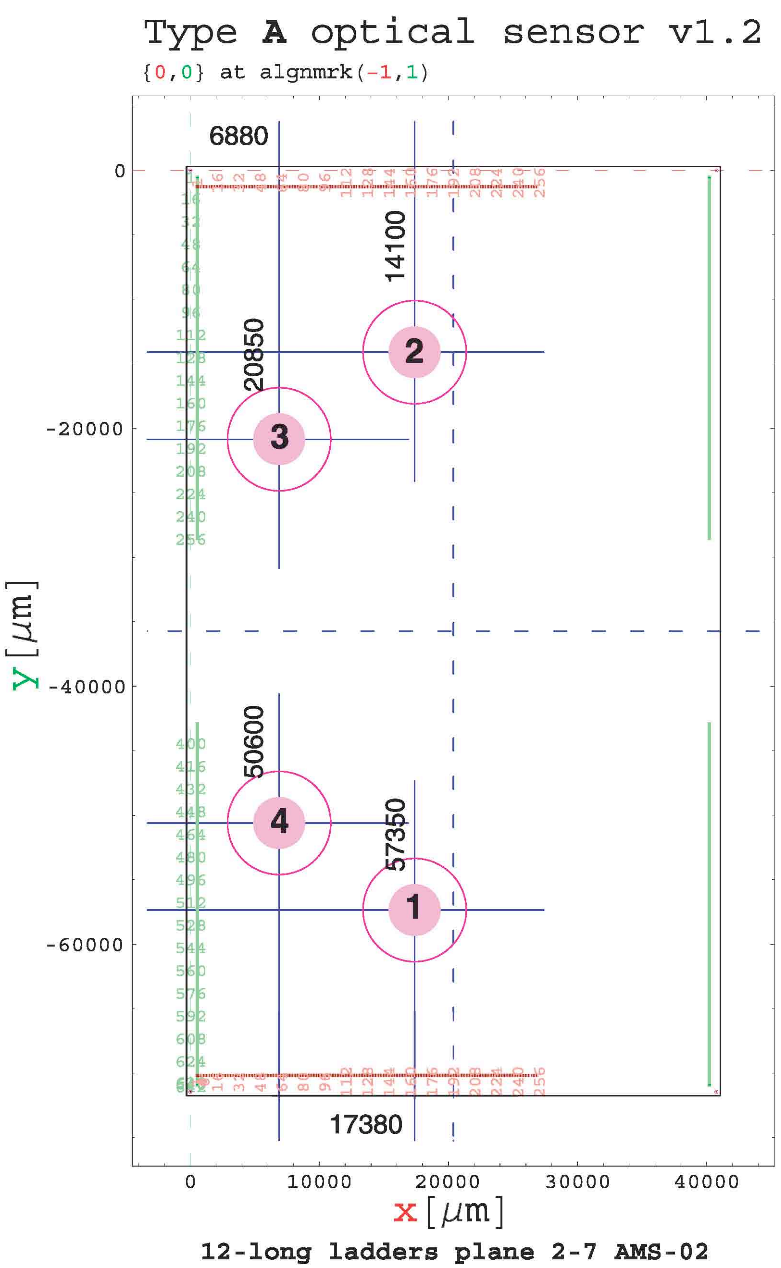
Laser beam access throught silicon ladders

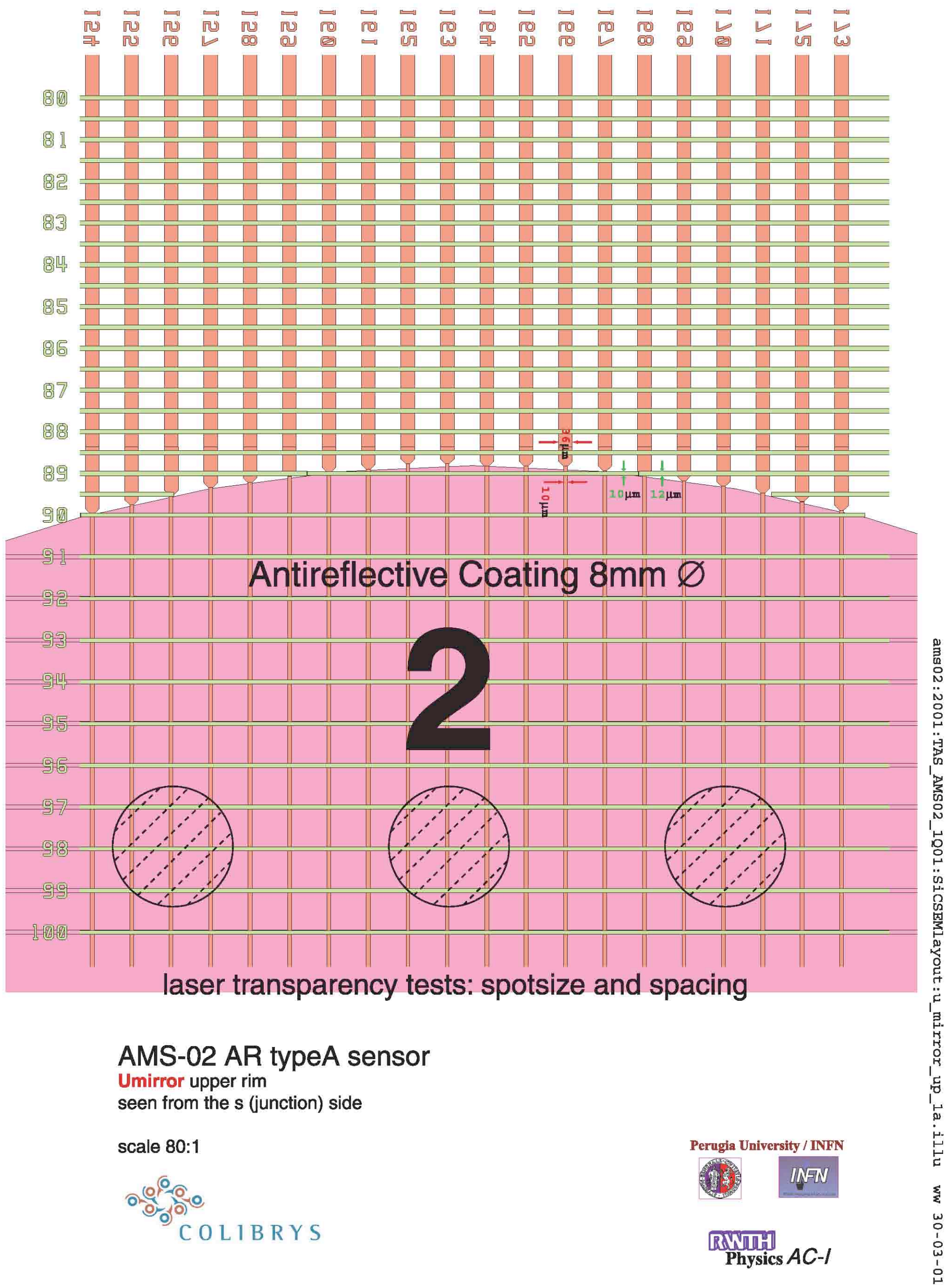
Installation of ladders on support planes

Thermal bars installed on external planes



Alignment silicon sensors





AMS alignment Si sensors

Double sided

110(27.5) μm y (⊥B)

Readout/metallization(implantation) pitch

208(104) μm x (||B) readout(implantation/metallization) pitch (ohmic side)

high resistivity (>6kΩ)

300 μm thickness

Biassing by punch through

low rate, low rad. load (i.e. LEP style) design

$8m^2$

Alignment silicon sensors

Si „Ladders"

antireflective areas

Laser beam(s)

- **1082 nm**
- **0.5 mm diam**
- **0.5 mrad div.**

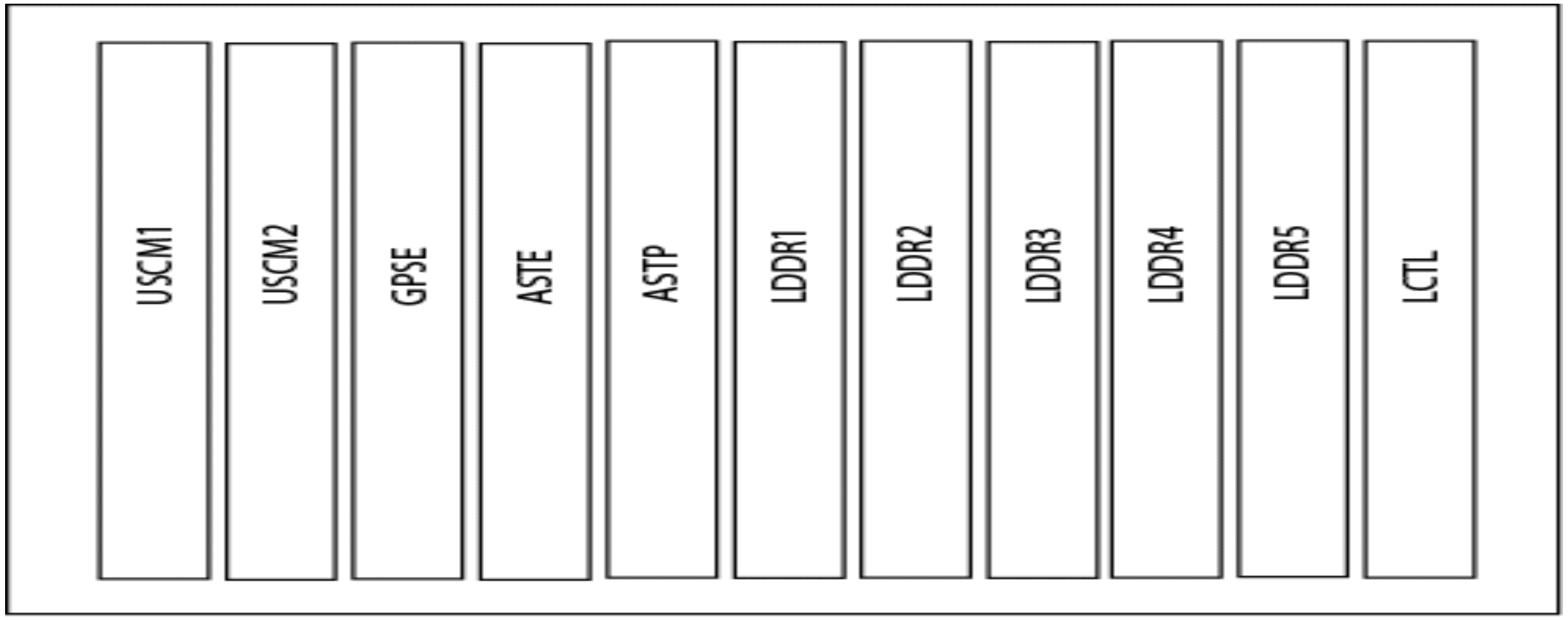
AMS-02 TAS

Short description of TAS electronics

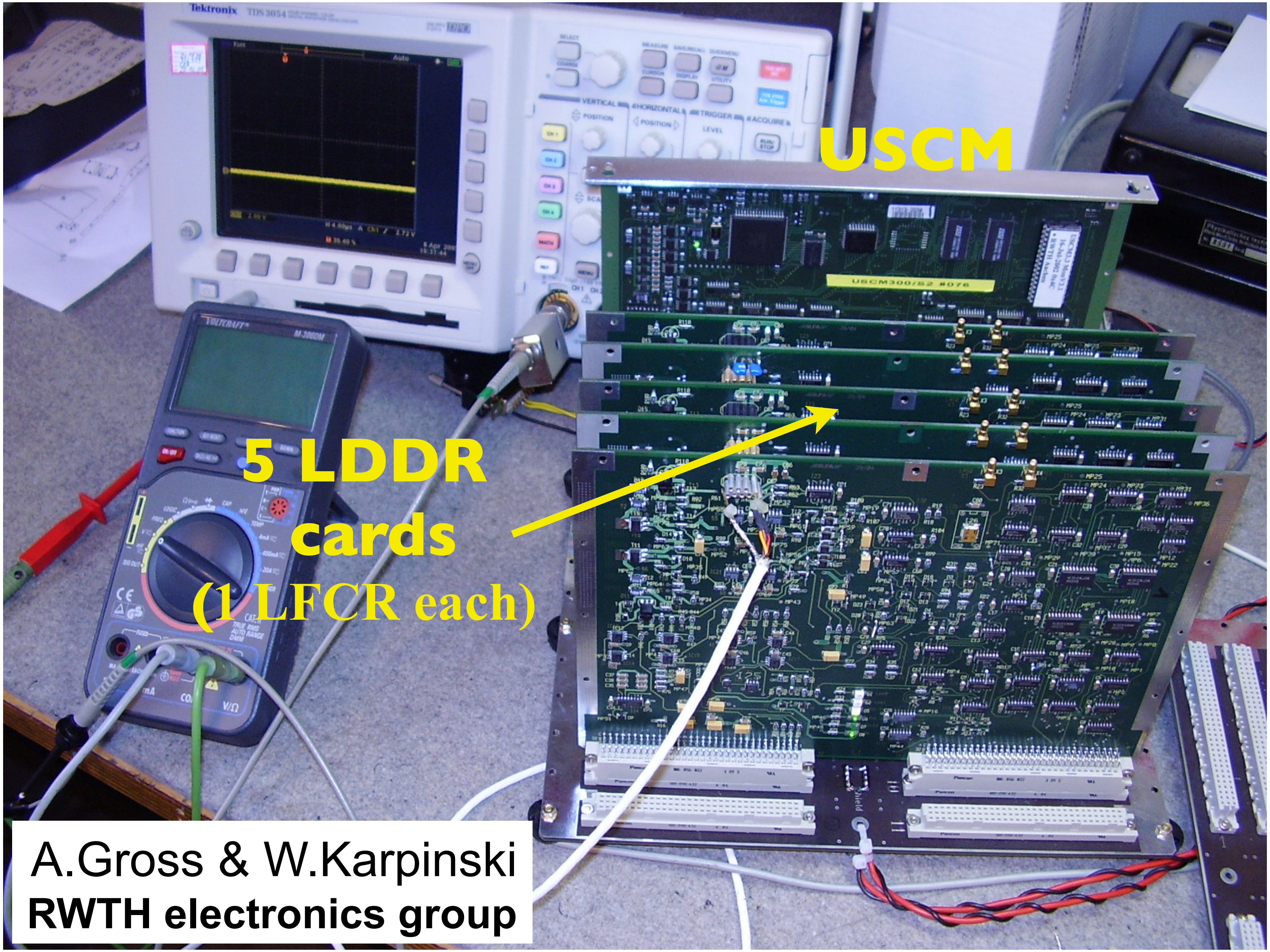
(detailed description of M-Crate tests can be found in the Electronics ADP from Giovanni Ambrosi)

System electronics schematic

- **The Laser Electronics is located in M-Crate**
- **It consists of 6 boards:**
  - 5 LDDR (laser diode driver)
  - 1 LCTL (trigger distribution)
- **Each LDDR drives two laser diodes**
- **The Laser system is controlled by two USCMs**
- **There are 3 additional modules in M-Crate**
  - 1xGPS module
  - 2xASTE

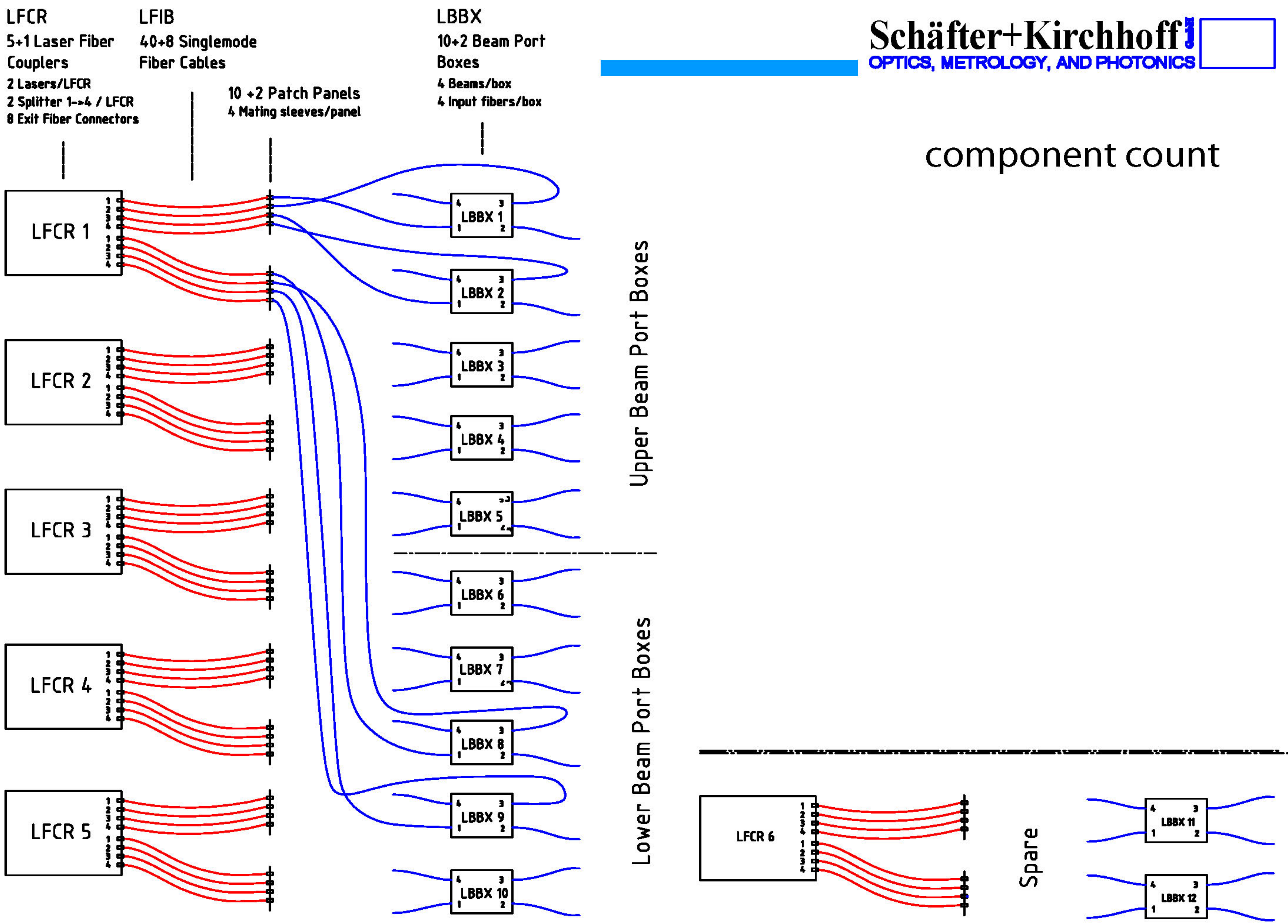


System electronic schematic

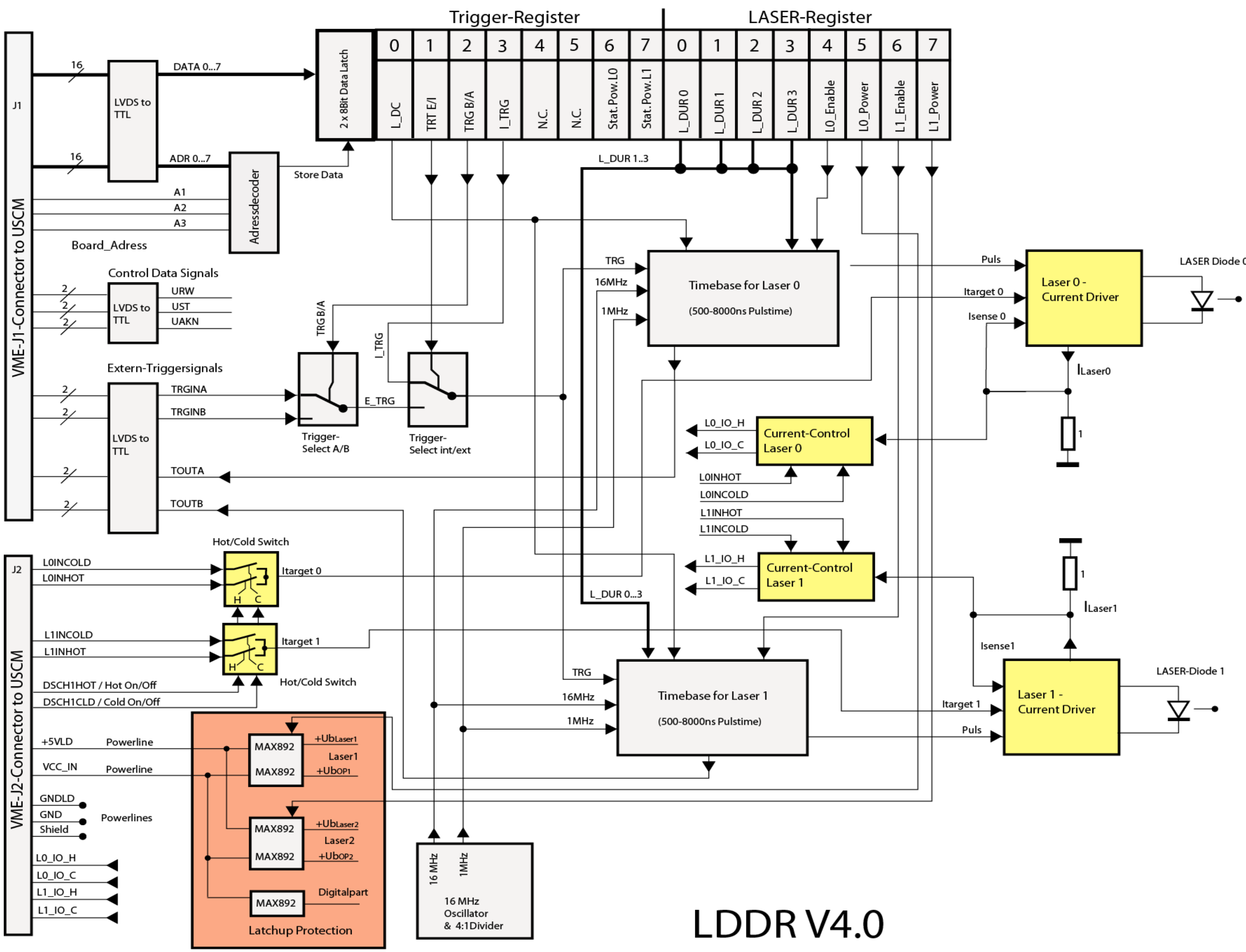


A.Gross & W.Karpinski
RWTH electronics group

System electronics schematic



System electronics schematic



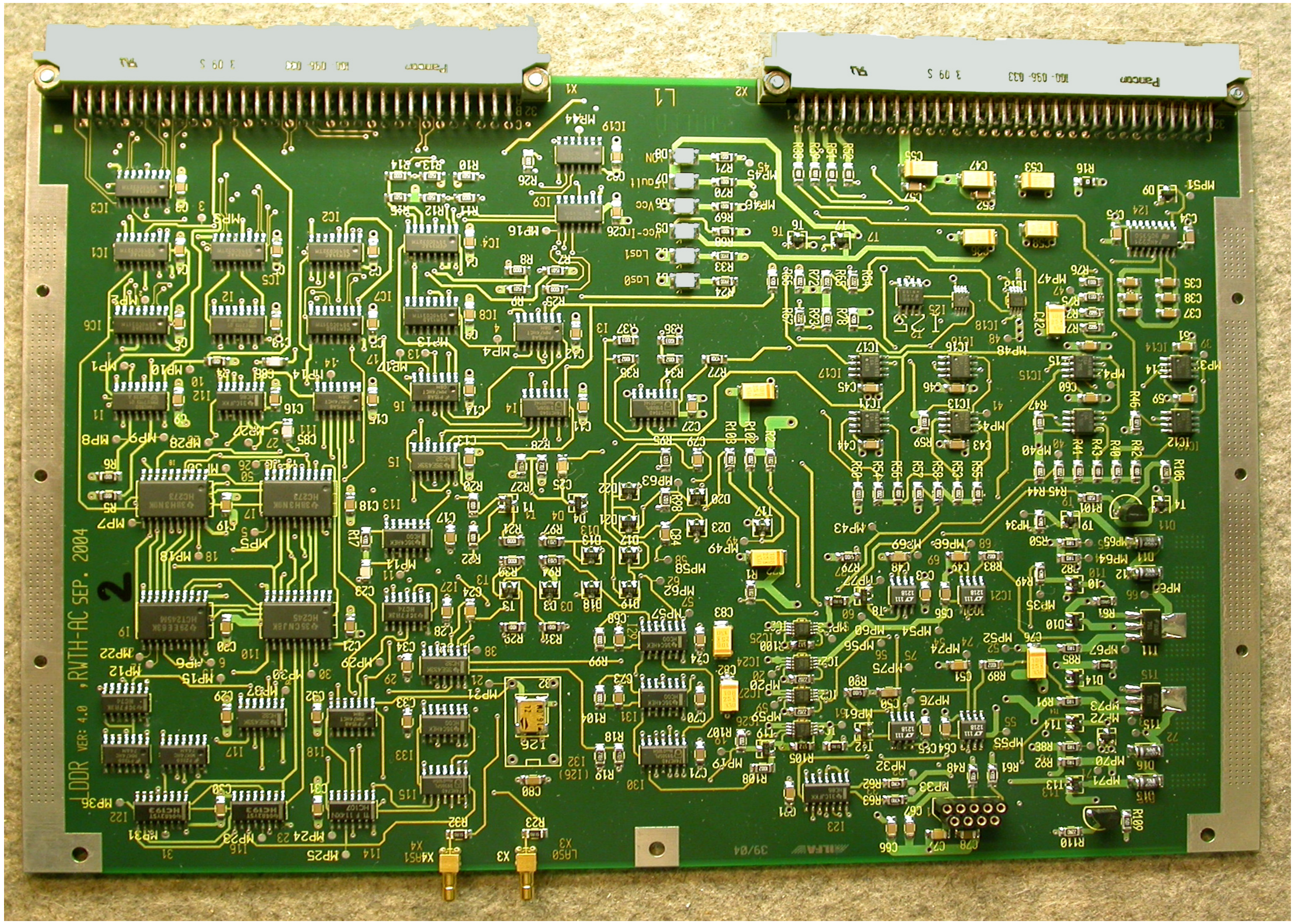
Block Diagram of LDDR

1 LDDR board is associated with 1 LFCR box and drives 2 Laser diodes

Essentially all registers and active circuits are 2-fold redundant

System electronics schematic

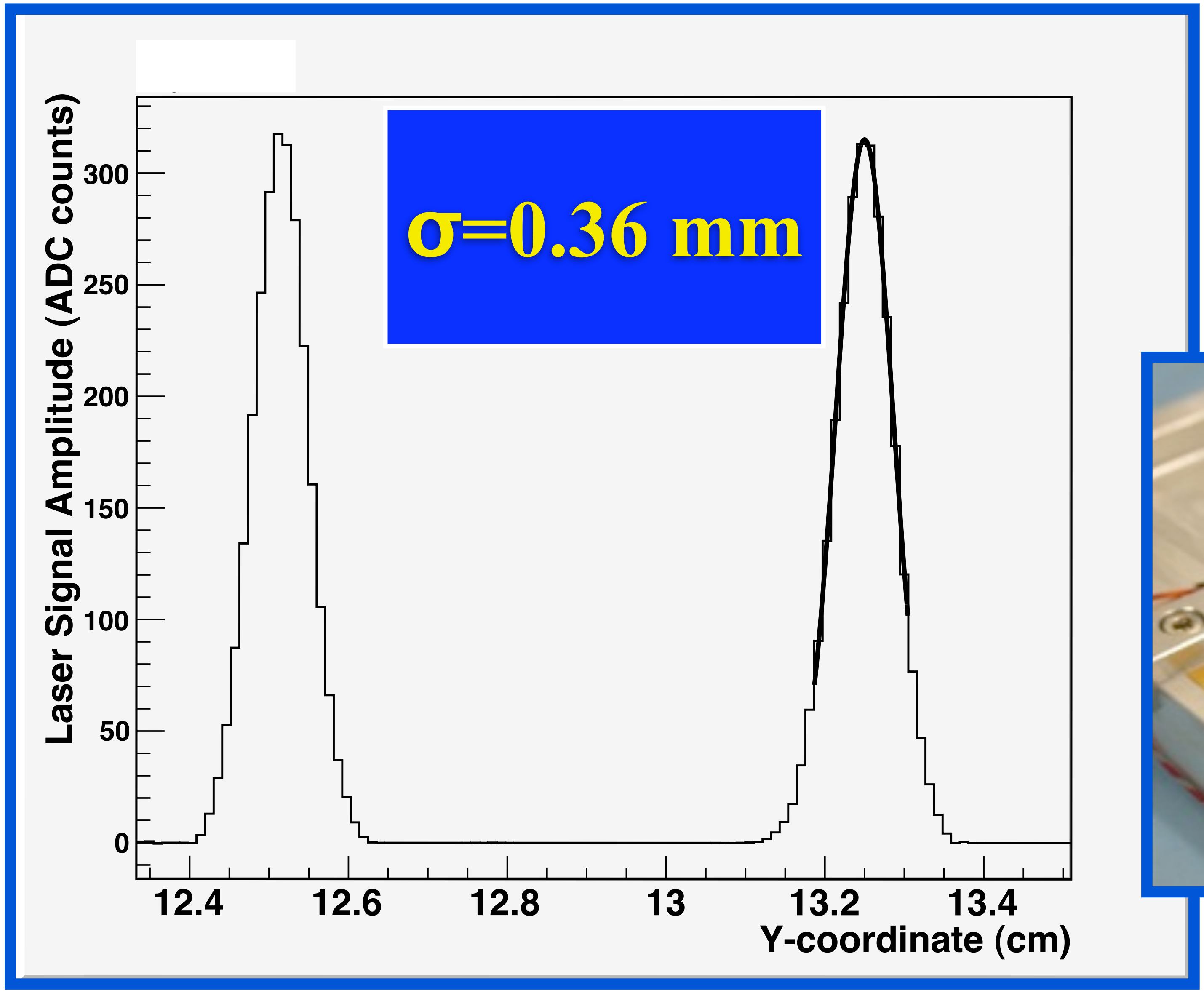
- **Power consumption of LDDR:**
  - digital part: +5V@ 170 mA
  - analogue part: +5V@ from almost 0 to 200 mA

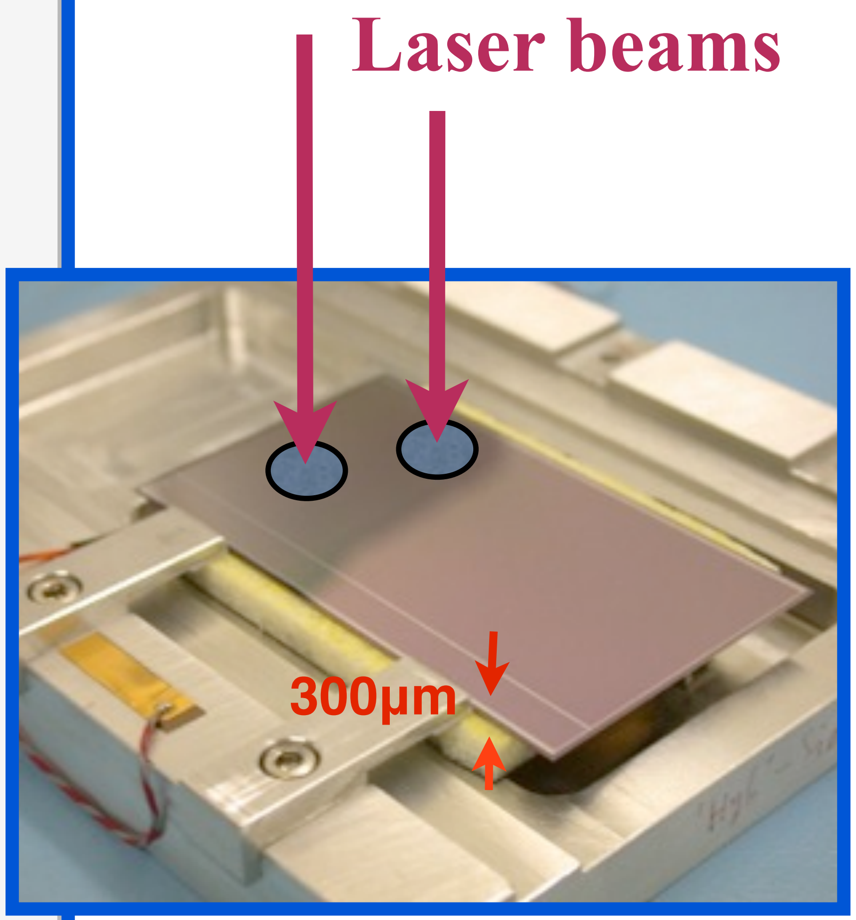


LDDR Board

Laser Signals seen by the Tracker

Typical AMS-2 laser single event signal as seen on silicon a wafer.





The beam position is obtained performing a gaussian fit to the detected cluster on the ladder.

AMS-02 TAS

(basic system description)

System features

TAS properties

Light weight (4 kg)

Low power (< 0.1 W)

Fast data taking (20s)

Highly accurate (< 5µm)

Low power laser diodes

100 nJ pulses are sufficent for observing signals in 8 successive layer

Antireflective coating **mandatory:** $n_{Si} = 3$

System features

The Tracker Alignment System (TAS) generates laser energy from ten independent laser diodes, pairs of the diodes contained within five Laser Fiber Coupler (LFCR) boxes.

This energy is generated by Eagleyard EYP-RWL-1083 infrared (1082 nm) laser diodes with a maximum power output of 80 mW.

Each laser diode will emit at a maximum 1 kHz interval with a maximum of 8 μs pulse duration when operating.

Each laser diode's emissions are split into four output fibers, each with approximately one quarter of the total power output.

The operation of the TAS consists of less than 1% of the AMS-02 operational time.

The LFCR boxes are light tight and can not release any laser emissions with the exception of the fiber ports where laser emission are nominal design features.

System features

Laser light sources generated within five light tight boxes exterior to the Tracker, mounted to the M-Frame (TRD M-Structure).

Each box contains two lasers diodes that can operate at:

- **1082 nm**
- **1.0 kiloHertz pulse frequency max**
- **8.0 microsecond maximum pulse duration.**
- **80mW continuous operation power (not an operations mode supported on AMS-02)**

Within each laser source box, the emissions from the two laser diodes are split into four beams, each with approximately 20mW of power if the lasers were to be continuously powered.

Each of these split beams is guided by a single fiber matched and bundled and taken to a FC-type connector.

Internal optics misalignment or fault results in no laser emission through fiber and contained beam.

System features

Outside of the box fiber optics cables connected with a FC-type connectors contain and direct the laser energy, with a single fiber per split beam.

All fibers route the laser energy from each box to the interior of the Tracker.

The fibers are split between the top and bottom (w.r.t. the Tracker) and terminate at five beam ports on each of the 2 Tracker outer planes.

Each beam port (LBBX) takes the energy from four fibers and directs it along the central axis of the Tracker to illuminate the silicon sensors.

Tracker volume is design to be light tight, including shielded vents that preclude exterior light from entering, or interior laser sources from exiting.

Tracker Structure acts as beam stop if misalignment occurs.

System features

Rupture/breakage of fiber path:

System is design to minimize the potential for breakage (clad, jacketed and armored fibers that are bundled within a sleeve).

System features

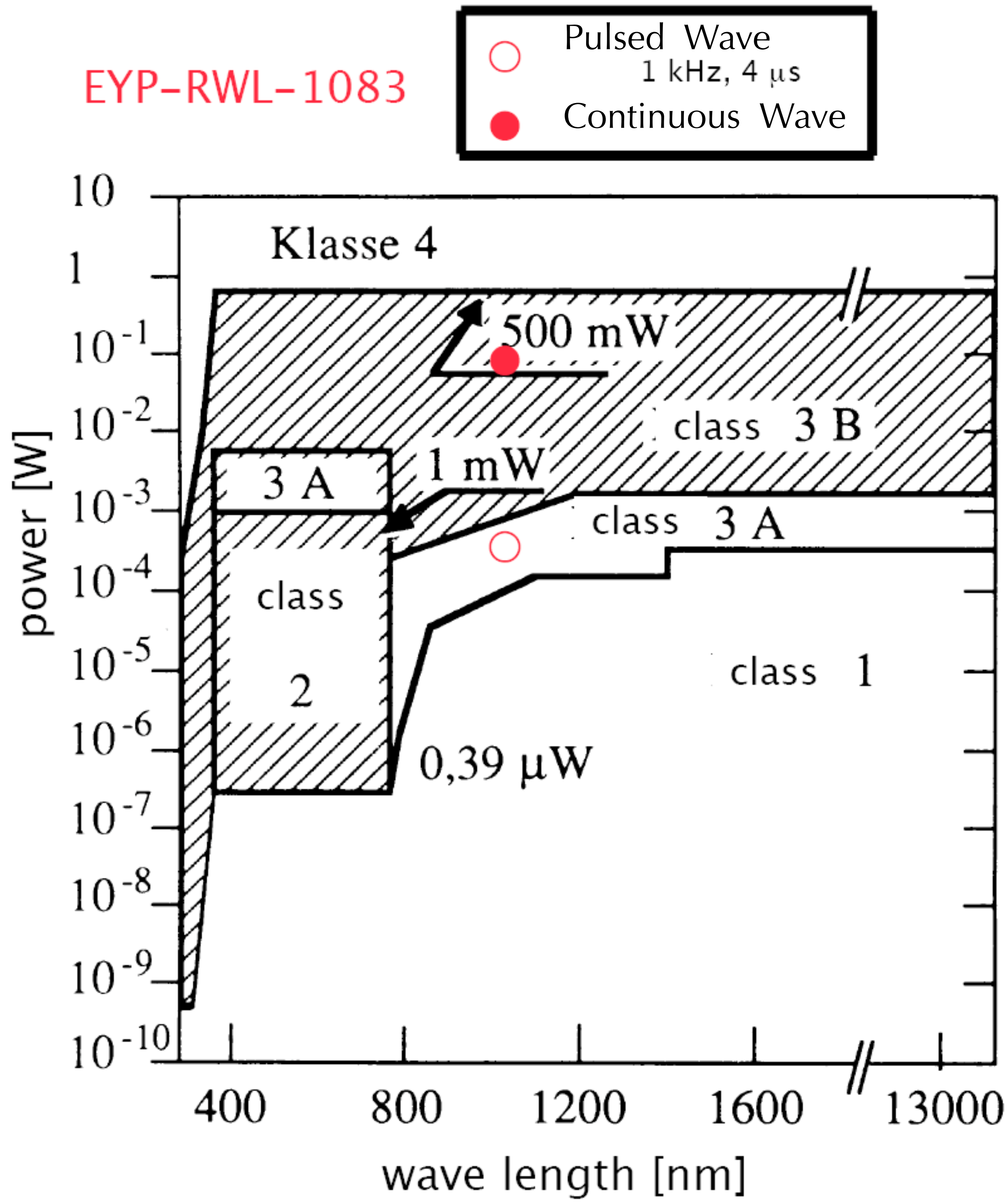
Ridge Waveguide Laser

GaAs Semiconductor Laser Diode

Characteristics at T_{amb} 25°C

Parameter	Symbol	Unit	min	typ	max	Measurement Condition
Center Wavelength	λ_C	nm	1070	1080	1090	
Spectral Width (FWHM)	$\Delta\lambda$	nm			1	
Temp. Coeff. of Wavelength	TC_λ	nm / K		0,4		
Output Power	P_{opt}	mW		80		
Slope Efficiency	η_d	W / A	0,5	0,7		
Threshold Current	I_{th}	mA		20	30	
Operational Current @ 80 mW	I_{Op}	mA		100	130	
Cavity Length	l_C	µm		750		
Divergence parallel (FWHM)	$\Theta_{\|\|}$	°		10		
Divergence perpendicular (FWHM)	$\Theta_\perp$	°		40		
Polarization				TE		
Mode Structure			Fundamental Mode			

AMS-02 Laser Diode Output Classification



Continuous Wave is NOT used in AMS-02 operations

AMS-02 TAS
(A more detailed description of the System)

AMS-02 tracker alignment control system (TAS)

document for
phase II AMS Safety report
MS-word TAS_sysSaf_v2.1   181kB

v2.1 30-Jul-2005

in response to information request #51
of the Phase II action item list
(AMS-02_TIM_Safety_Act#B4F7E.xls)

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0 Document overview

1 Introduction

With the AMS-02 Si-Detector charged particle tracks are traced at 8 space points in a $1m^3$ size B-field to an accuracy of better than 10µm in the most important axis perpendicular to the main component of the field.

The AMS tracker has to cope with a wide range of environmental conditions. Of major concern are the vibrations during the transport before deployment and the rapid periodic changes of the detector temperature due to solar radiation and cooling while in the shadow of Earth.

The Tracker Alignment Control System (TAS) provides optically generated signals in the 8 layers of the Si - Tracker, that mimic straight (infinite rigidity) tracks. It has been shown with AMS-01 [1, 2, 3], that these artificial straight tracks allow to follow up changes of the tracker geometry with a position (angular) accuracy of better than 5 μm (2 μrad).

The AMS approach to Si-tracker alignment control using IR laser beams fulfills the requirements of a space born experiment:

1 Light weight (4 kg)
2 Low power (<100mW peak, ca. 1mW averaged)
3 Proven as being safe in use both on ground and in space
4 Fast, autonomous and low overhead operation (< 1% of tracker running time)
5 Precision exceeding the tracker resolution (8μm) with a small number (<100) of laser shots

The particle tracker and the TAS use the same Si-sensors both for particle detection and alignment beam recording. The TAS can generate position control data within seconds at regular time intervals (4 – 6 / orbit), for example while the ISS flies into the shadow of Earth or coming back into the sunlight.

The realization of the TAS is based on:

1 The experience gained with AMS-01
2 A series of rigorous space qualification (thermal, vacuum, vibration) tests (most at the 1. Physikalisches Institut 1b, RWTH Aachen, Aachen, Germany)
3 The use of space flight compliant components
4 The application of documented space flight compliant working procedures at our manufacturer

2 TAS system components

After an overview of the system geometry (2.0) the description of the TAS starts with the beams (2.1) as they are used for alignment control. This is followed by the optical components (LBBX; 2.2) that deliver the beams into the tracker volume. Then the fibres (LFIB; 2.3) delivering the optical signal to the LBBX are described. We continue with the generation of the optical signal and its coupling into the fibres (LFCR, 2.4). We finish with an overview of the driving electronics (LDDR, 2.5).

2.0 *TAS geometry*

The AMS02 - tracker is equipped with 2 x 10 pairs of alignment control beams (altogether 40,). 2 pairs of alignment beams originate in each of the 5 beam port boxes (LBBX) on both of the outer tracker plates (#1 and #5). Both upward and downward going beams use the same roads defined by the anti-reflective areas on the Si and the cutouts in the ladder cladding .
TAS has 10 laser diodes mounted in pairs inside the Laser fibre couplers (LFCR). The optical output of one laser diode is split equally on four output fibres. The parameters of the driving signals are individually controlled for each diode. While operating in space no more than 2 diodes are operated concurrently.

2.1 *Laser beam parameters*

The wave length (lambda = 1082nm) of these beams has been chosen such as to penetrate all 8 Si detector layers of the tracker at once. At this wavelength only a small fraction (approx. 10% / 300 μm Si) of the generated photons are absorbed. The effective transparency of the Si (approx. 50%) is however dominated by the amount of the surface fraction not covered with Al (traces) for contacting the readout electrodes.

The beams are circular (radius <.7 mm) and have small divergence ($\varepsilon < 1$ mrad). The requirement on parallelism ($\phi < 5$ mrad) is set by the diameter of the openings for the roads (7 mm) in the Si ladder shields and the ladder mounting precision.
As we have LBBX on both ends of the roads these are terminated and no IR radiation can directly escape from the tracker volume (for electrical reasons the tracker volume is designed for light tightness such that no scattered IR beams can exit the volume). From layer to layer The signal I_0 is attenuated by a factor of 2 due to the optical properties of the Si, i.e. after 8 layers the remaining intensity will be $4\ 10^{-3}\ I_0$.
Connected to the driver circuit (LDDR) the lasers can only be pulsed. With the best possible control of all coupling losses the maximum pulse energy per beam (at the LBBX output port) will be 30 nJ. Judging by the experience from recent laboratory tests we expect to run at 8 nJ or less. The Si response is strongly temperature dependent. In consequence we will adjust the diode pulse current at low ambient temperature such that the signal remains sufficient for analysis. Repetition rates are limited by the capacity of the tracker readout system to 1 kHz.

2.2 *Laser beam port boxes* (LBBX's)

The beams enter the tracker volume through the bottom of the beam port boxes LBBX's mounted on the outer face of the two outer tracker support plates Four (2x2) optical fibres connect to each LBBX. The divergent fibre outputs are collimated by projection optics (parallel to the tracker endplate surface) at each of the 4 input ports. The beams are redirected perpendicularly into the tracker volume by the mirrored surfaces of the 2 quadrilateral prisms at the center of the LBBX .
It is mandatory that the beams remain inside a cylindrical tube of 6 mm diameter and 1 m length centered on each of the output ports.
LBBX bodies are made from standard Aluminum (AlSi1MgMn - AW 6082). Lens- and mirror - holders are fabricated from "German Silver" Cu Ni12 Zn24 (Ns 6512). The manufacturer will provide documentation about the materials used for the lenses and the mirrors (typical transverse dimensions 3mm, typical mass 100mg).
LBBX are fixed into a recess with 3 M2.5 screws to the upper / lower flange of the tracker (for details see tracker drawings). The weight of a LBBX (without fibres connected) is <40g.

2.3 *Laser fibres* (LFIB's)

The fibres do run from the LBBX's to the rim of the tracker plate at (x=0, y= -700), where they are held in small patchpanels (LFIB-P4) holding subminiaturized fibre connectors (< 5g /connection). At the upper tracker plate (#1) connecting fibres run directly from this transition point to the Laser Fibre Couplers (LFCR). These will have to be installed after tracker insertion into the magnet bore (and TCCS preparations) and before the mounting of the upper ToF-TRD assembly. At the lower tracker plate (#5) the connecting fibres have to be in place before tracker and ACC insertion.
Fibres are of the Corning HI 1060RC type with cladding (diameter 0.08 mm) and jacket (diameter 0.165 mm). They are "armed" with Nylon (diameter 0.9 mm). Beside the subminiature connection at the tracker flange rim we use standard fibre connectors (FC). Vendor specific details will be provided by our manufacturer. For routing fibres (4 – 8) will be bundled in standard braided installation sleeves and fixed with tie wraps to cable fixation points (see fig. 6). The bending radius for individual fibres / fibrebundles must exceed 20 mm / 40 mm. At their LFCR end the LFIB's pass through the MLI enclosure of the TRD.

2.4 *Laser fibre couplers* (LFCR's)

There are 5 Laser fibre couplers mounted as a block against the lower x=0,-y node of the TRD M-structure Each coupler houses 2 diode coupling units and 2 4-fold splitters. The total weight of the 5 couplers is < 1500g. The fixation scheme (4 bolts M3 / LFCR) has been checked by Aachen engineering (report available).
LFCR bodies are made from standard Aluminum (AlSi1MgMn - AW 6082). Lens- and mirror - holders are fabricated from "German Silver" Cu Ni12 Zn24 (Ns 6512). The manufacturer will provide documentation about the materials used for the lenses (typical transverse dimensions 6mm, typical mass 750mg).
All glass parts are enclosed (coupling optics). The fibres including the splitters are cladded and jacketed as all our fibres.

The are several venting pathways (gaps in covers, optical connectors, etc.). During the vacuum test (Aachen, spring 2005) venting speeds will be tested (Vol. < 200 cm^3).

2.4.1 Laser diodes

We use Eagleyard EYP-RWL-1083 Laser diodes with 80mW max. output power. The diodes are mounted in a standard windowed TO-9 package. The driving current is limited to 100mA at typically 2 Volt. This Laser belongs to category 3b (a detailed account of safety aspects is given in section 3).

2.4.2 Diode fibre coupling optics

The coupling optics adapts the (rotationally asymmetric) diode emission pattern to the acceptance of the signal transporting fibre (core diameter 6.0 µm). In addition to a perfect optics design a reliably adjustable diode position is essential for achieving high (>60%) coupling efficiency. Furthermore optical back-termination is required for preventing diode damage through back-reflection in the fibres. The AMS-02 design by Schäfter & Kirchhoff is derived from the design successfully used with AMS-01 (see appendix 5.2). Besides of intensive tests in Aachen the current design has been used with other (ESA) ISS experiments.

2.4.3 Fibre splitters

The fibre splitters provide a highly stable equipartitioning of the optical output power of a single Laser diode into 4 outputs. The splitters are delicate in handling. Therefore they have been incorporated into the LFCR. Both input and output lines of the splitters are coiled up and fixed to the body of the LFCR

2.4.4 Optical output connectors

The splitters end in FC type optical feedthroughs (fig. 8/9). There will be fibres (LFIB) connected to each of the 8 output connectors.
The maximum output energy per connector per pulse will be 55 nJ (in order to be able to deliver 32 nJ in spite of the unavoidable coupling losses between the LFCR output and the LBBX output).

2.4.5 Electrical input connectors

The switched diode driving current comes come from the laser diode driver (LDDR,) housed in the M-crate. The connector will use the standard d-sub 9 format

2.5 *Laser Diode Drivers* (LDDR's)

The Laser diodes are driven from a pulsed current source specifically designed to suppress spikes in the driving current. The pulse width can be set in steps of 0.5 µs from 0.5 µs to 8.0 µs. Rise/fall time are typically 60 ns. The output current (<200 mA) can be set with 8 bit resolution. All Control is through the USCM's via the M-crate backplane. The development of the LDDR [4] is approaching the construction of a set qualification modules The M-crate houses 5 LDDR's (2 current sources each) serving the 5 LFCR's. The output cables run from the front panels of the LDDR's to the LFCR's mounted on the M-structure carrying the TRD. These cables have to pass the MLI of the TRD.

3 *The IR radiation levels*

3.1. TAS laser power basics

1. The LFCR diode *EYP-RWL-1083* operated at the maximum(tracker DAQ) LDDR setting delivers an average power of

$$P_{avg} = P_{CW} \cdot \text{duty factor}$$

$$= 80 \cdot 10^{-3}\,\text{W} \cdot 8 \cdot 10^{-3}\ (4 \cdot 10^{-3}) = 400\ (200)\ \mu\text{W}$$

$$\text{duty factor}_{max} = \text{rep rate} \cdot \text{pulse length} = 1000\ \text{s}^{-1} \cdot 8\ 10^{-6}\ \text{s} = 8 \cdot 10^{-3}$$

$$(\text{duty factor}_{DAQ} = \text{rep rate} \cdot \text{pulse length} = 1000\ \text{s}^{-1} \cdot 4\ 10^{-6}\ \text{s} = 4 \cdot 10^{-3})$$

max. pulse energy at diode window:

$$w_{pulse} = P_{avg} / \text{rep rate} = 400\ \text{nJ}$$

max. pulse energy at a single LBBX output (1 laser diode feeds 4 beams on different LBBX):

$$w_{beam} = w_{pulse} \cdot \eta_{coupler} \cdot \eta_{splitter} / 4 \cdot \eta_{FC} \cdot \eta_{FC} \cdot \eta_{LBBX}$$
$$= 400\ \text{nJ} \cdot 0.6 \cdot 0.9/4 \cdot 0.85 \cdot 0.85 \cdot 0.8 = 31.2\ \text{nJ}$$

with η_i being the transfer efficiency at the various transitions in the light transport system (FC connector, LBBX beamport, etc.., these values can be achieved with careful adjustments, but they are somewhat smaller than the theoretical limits)

In ANSI Z136.1-2000 the power limits for a class 3b laser are defined as follows :

a)	P_{CW} (1.05µm < λ < 1.40µm)	≤	$125 \cdot 10^{-3}$ W
b)	P_{avg} (1.05µm < λ < 1.15µm)	≤	$500 \cdot 10^{-3}$ W
c)	w_{pulse} (1.05µm < λ < 1.4µm)	≤	$125 \cdot 10^{-3}$ J

Hence the design safety factor of TAS at the beamport (LBBX) output is :

d) $\quad w_{pulse}^{\ limit} / w_{beam} \quad = \quad 125 \cdot 10^{-3}/31.2 \cdot 10^{-9} = 4 \cdot 10^{6}$

2. general position measurement related laser power aspects:

The pulse length for alignment runs in space will be adapted to the tracker readout integration time (3 – 4µs) hence shorter than the maximum possible (8 µs) from the LDDR. For example the generation of a 22 mip equivalent signal in the AMS Si plane 1(8) (farthest from the LBBX on plate 5 (1)) requires an energy of approximately 15 nJ out of the beamport. Since the laser beam is ca. 1.4 mm in diameter the maximum signal strip then receives approximately 2.5(5) mips on the y (x) side.
Far above the read out noise the position measurement precision is proportional to the square root of the product of the pulse energy w_{pulse} and the number of pulses n_p . In consequence the alignment pulse energy can be traded with the number of pulses n_p observed.

3.2. **M**aximum **P**ermissible **E**xposure **data**

(adapted from ANSI Z136.1,
see example 11 in appendix B3 of the 2000 edition as well as
examples 4, 19 in the appendix of the 1993 edition)

1. (see ANSI Z.136.1-2000, tables 5a, 6; figs 4, 8a,
for **1083nm** pulses of ≤ **4µs** duration with **1 kHz** rep. rate ,
the **AMS02** case)

(repetitive pulse limit Eq. B10)

MPE / Pulse $= n^{-1/4} \cdot 5 \cdot C_C \cdot 10^{-6}$ J / cm^2
$=$ **0.5 µJ / cm^2**

(1). n $= f \cdot T = 1000\ s^{-1} \cdot 10\ s = 10^4$
(2). C_C = 1 (see table 6)

2. **MPE(cumulative)** = n • MPE/pulse
= **5 mJ / cm^2**

3. average radiance = MPE(cumulative)/T
= 0.5 mW / cm^2

4. estimated **N**ominal **H**azard **Z**ones
(**N**ominal **O**cular **H**azard **D**istance, minimum distance for safe working)

(1). direct viewing

(a). at a LBBX output

ε_{LBBX} = 1mrad divergence, a_{LBBX} = 1.4 mm diameter)
$r_{NOHD} = [(1.27 \cdot w_{beam} / (\textbf{MPE / Pulse}) - a_{LBBX}^2)^{1/2}] / \varepsilon_{LBBX}$
$= [(1.27 \cdot 0.031\ \mu J\ / (\textbf{0.5}\mu J/cm^2) - 0.14^2)^{1/2}] / 10^{-3}$
= 2.43 m

(b). from an open LFCR output (or broken LFIB)
(see fibre specs,
ε_{LFIB} = 0.15 rad divergence, a_{LFIB} = 0.006 mm diameter)
$r_{NOHD} = [(1.27 \cdot w_{pulse} / (\textbf{MPE / Pulse}) - a_{LFIB}^2)^{1/2}] / \varepsilon_{LFIB}$
$= [(1.27 \cdot 0.4\ \mu J \cdot 0.6 \cdot 0.9/4 / (\textbf{0.5}\mu J/cm^2) - 0.0006^2)^{1/2}] / 0.15$
= 2.5 cm

(c). at the diode window
(see diode specs,
ε_{diode} = 0.5 rad divergence, a_{diode} = 0.020 mm diameter)
$r_{NOHD} = [(1.27 \cdot w_{pulse} / (\textbf{MPE / Pulse}) - a_{diode}^2)^{1/2}] / \varepsilon_{diode}$
$= [(1.27 \cdot 0.4\ \mu J / (\textbf{0.5}\mu J/cm^2) - 0.002^2)^{1/2}] / 0.5$
= 2.0 cm

3.3. Summary Maximum Permissible Exposure data

The data shown in the preceding subsections do clearly demonstrate that AMS TAS power levels are far below the limiting levels imposed by ANSI Z.136.1 (see 3.1.1.d).
The TAS IR radiation is completely contained under all conceivable circumstances. The system is designed such that it is gracefully degrading even in cases were sub-components are destroyed (broken fibres etc.) during handling in the shuttle or on ISS.
Furthermore TAS is generally active for only 1% of the AMS data-taking.
The highest power densities occur in the tracker volume itself (see 3.2.4.1.a), which is a closed light tight inaccessible sub-volume of the AMS-02 experiment. At these small direct viewing power levels we have not evaluated the indirect (i.e. reflected) intensities.
Each of the LBBX that deliver the IR beams is controlled separately and its output is monitored by the signals from the Si-detectors, so the proper function of this component is permanently checked.
Due to the optical properties of our fibres there is no risk in case of a fibre rupture beyond the limits of a tiny keep out zone (see 3.2.4.1.b) with radius $r_{NOHD} \approx 1$inch.

References

1 J. Vandenhirtz et al. Space flight experience with the AMS infrared tracker alignment system, Proceedings of the 27th International Cosmic Ray Conference, (ICRC2001), Hamburg , Germany, 2001, Vol.5, session OG, pp 2197-2200 (paper icc 1574) (http://www.copernicus.org/icrc/papers/icc1574_p.pdf)

2 W. Wallraff et al. The AMS Infrared Tracker Alignment Sytem – From STS91 to ISS, 7th International Conferenceon Advanced Technology and Particle Physics, (ICATPP-7), Villa Olmo Como Italy 2001, M. Barone et al. (Eds.), World Scientific, Singapore 2002, ISBN 981-238-180-5. pp. 149-153 (http://nss2000.mi.infn.it/Manuscript/5_tracking/Wallraff.pdf)

3 J. Vandenhirtz, Ein Infrarot Laser Positions-Kontroll-System für das AMS Experiment, 2001 PhD thesis, RWTH-Aachen (http://sylvester.bth.rwth-aachen.de/dissertationen/2002/137/02_137.pdf)

4 A. Gross, AMSII Laser Driver, LDDR v: 4.0, Sep.2004 RWTH-Aachen 1. Physikalisches Institut 1b, electronics development (gross@physik.rwth-aachen.de)

5 *Appendices* (file KSC&LASSAF_AMS1a.pdf)

In order to help engineers unfamiliar with AMS Laser use in understanding the background of IR Laser use at AMS-02 have a look at 2 of the essential documents exchanged between the collaboration and NASA in 1997/8

5.1 NASA Laser use authorization for AMS-01 (pages KSC1 – KSC3) , issued Feb. 18 1998 at KSC 15 weeks before STS-91 lift-off.

5.2 AMS-01 Laser system description,

outline of laser based procedures,
ground support equipment for work at KSC,
authorization requests for potential Laser operators,

dated Sep. 4 1997, submitted 17 weeks after feasibility had been proven and 6 weeks before AMS-01 TAS was installed at ETH Zürich (pages AMS01_1 – AMS01_28)

AMS-02 TAS

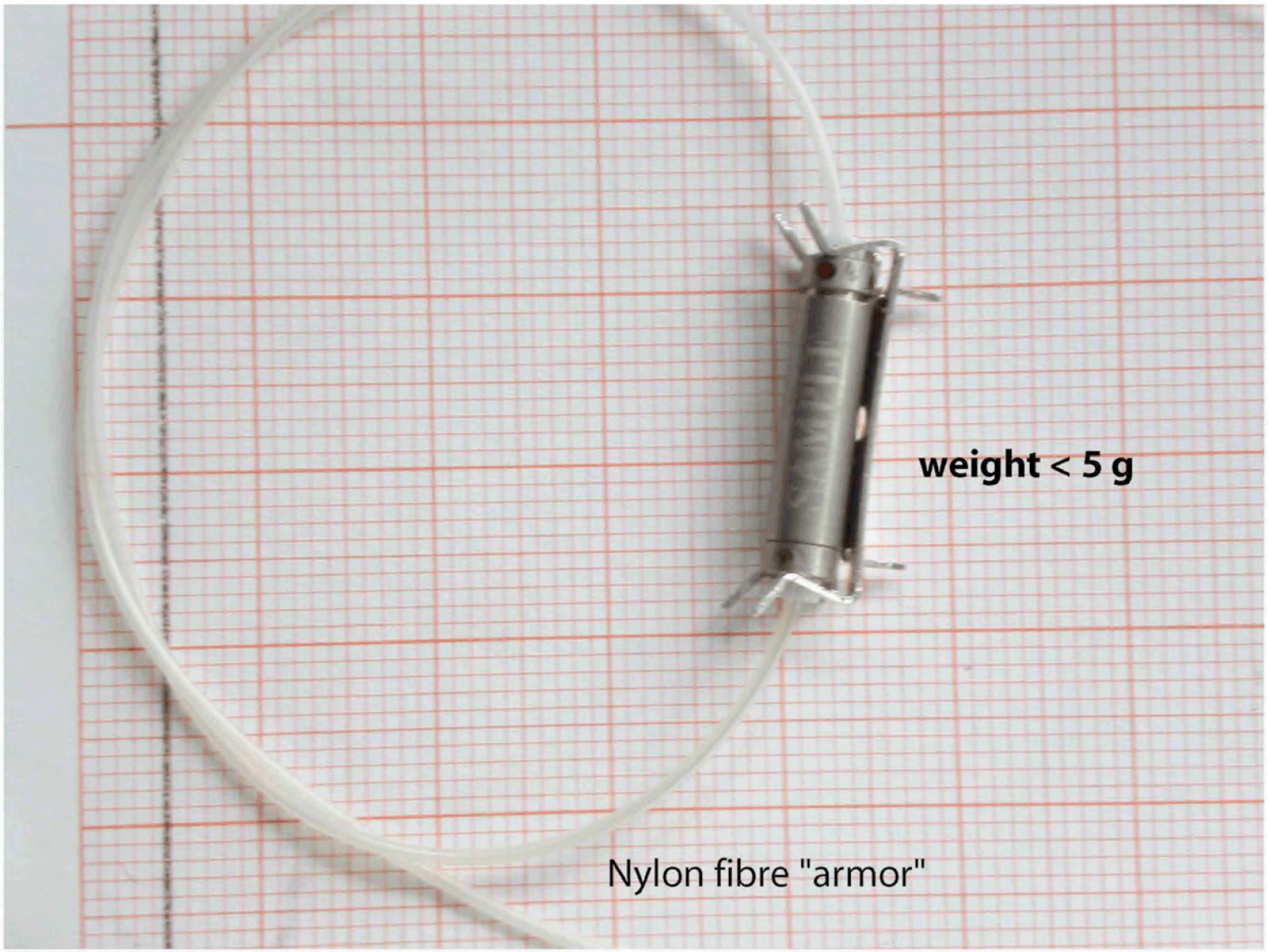
Optical Fibers

40 Optical fibers

AMS TAS LFIB's

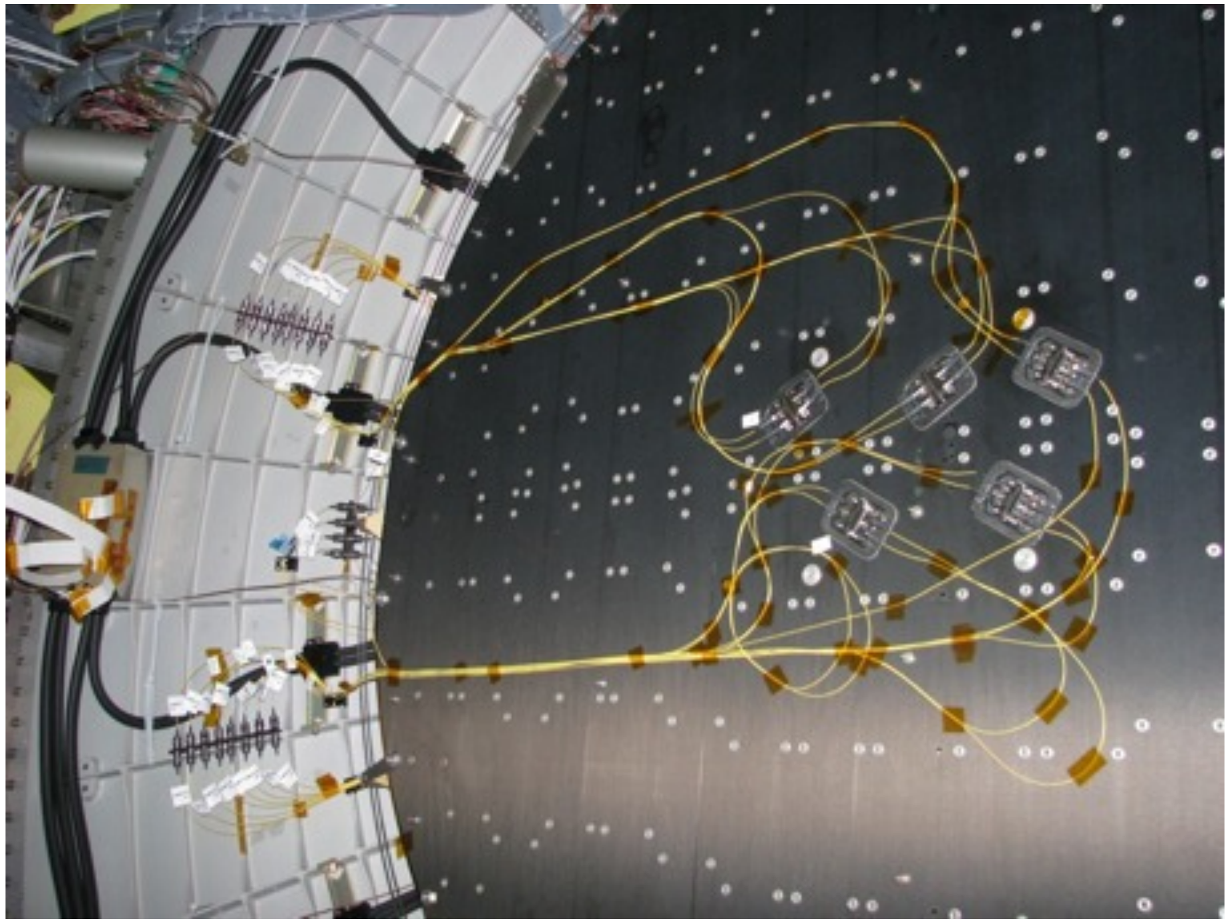
subminiature fibre to **fibre connector**

with **0.5 μm positioning accuracy** at the **fibre joint**

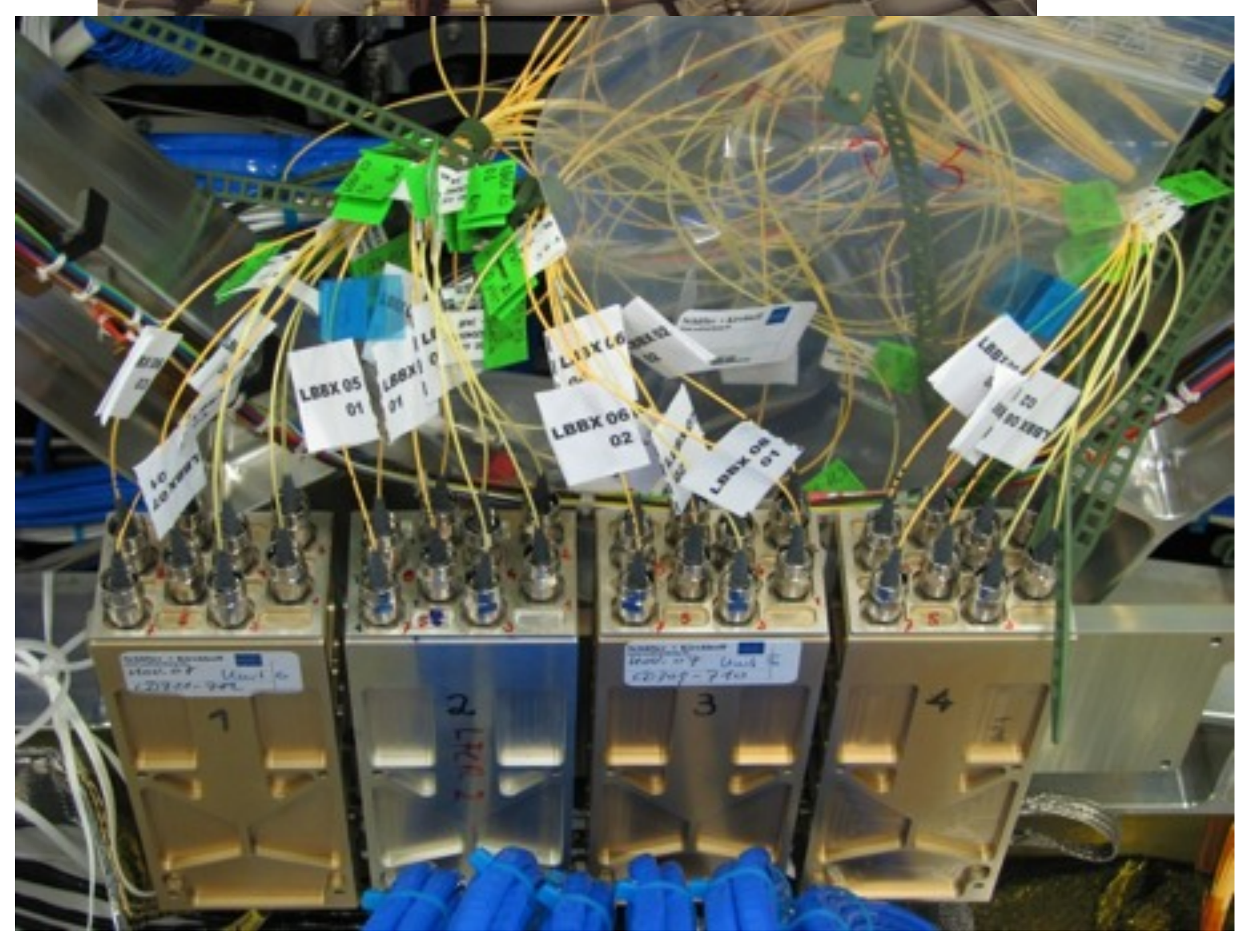


gridline
spacing 1mm

2004-12-05




3
4


LBBX 05
01
LBBX 06
02
LBBX 08
01
1
2
3
4

Optical Fibers (LFib) Protokoll

Schäfter + Kirchhoff

LFIB No. 01 - 20

Fiber Cables for TAS at AMS-2, RWTH-Aachen

Fiber Cables

Fiber Type	Corning HI1060, 5.9/125/250 μm
Cable Lengths	5000 mm
Connector Type	Diamond HPC-S0.66/M, Type FC-PC, core-centered < 0.5 μm
Return Loss	> 50 dB

Measurement

After installation to the tracker the transmisstion of the fiber cables are measured, -z -> +z:

Source:	Schäfter +Kirchhoff 51nanoFCM-1084 with Faraday isolator, splitter, output port 4, output power 2,57 μW
Detector:	Newport 818-SL/CM at Newport Model 840-C

Data

Cable		Connector at Tracker -z		Connector at Tracker +z		Measurement	
		Code	Insertion Loss	Code	Insertion Loss	Transmission	IL
No.	Color code	B7903327000...	dB	B7903327000...	dB		dB
1	sss	37	-0.1	38	-0.14	0.96	-0.19
2	ssr	35	-0.19	36	-0.11	0.95	-0.23
3	ssg	40	-0.12	39	-0.13	0.91	-0.43
4	srs	41	-0.14	42	-0.17	0.95	-0.21
5	srr	43	-0.17	44	-0.11	0.94	-0.28
6	srg	45	-0.21	46	-0.17	0.95	-0.24
7	sgs	50	-0.09	49	-0.25	0.92	-0.35
8	sgr	03	-0.2	04	-0.18	0.95	-0.21
9	sgg	02	-0.2	01	-0.17	0.94	-0.26
10	rss	05	-0.18	06	-0.17	0.95	-0.23
11	rsr	07	-0.18	08	-0.19	0.95	-0.21
12	rsg	10	-0.08	09	-0.11	0.94	-0.26
13	rrs	12	-0.07	11	-0.06	0.94	-0.26
14	rrr	16	-0.09	15	-0.12	0.95	-0.21
15	rrg	22	-0.05	21	-0.07	0.93	-0.33
16	rgs	26	-0.07	25	-0.08	0.93	-0.3
17	rgr	24	-0.14	23	-0.06	0.95	-0.23
18	rgg	30	-0.07	29	-0.12	0.94	-0.28
19	gss	31	-0.09	32	-0.12	0.95	-0.21
20	gsr	34	-0.18	33	-0.15	0.93	-0.3

Protokoll_LFIB.rtd

Schäfter + Kirchhoff GmbH
Kieler Str. 212, D-22525 Hamburg - Tel: +49 (0)40 853 997 0 - Fax: +49 (0)40 853 997 79 - eMail: info@SuKHamburg.de - Web: http://www.SuKHamburg.de

AMS-02 TAS

Laser Beam Port (LBBX)

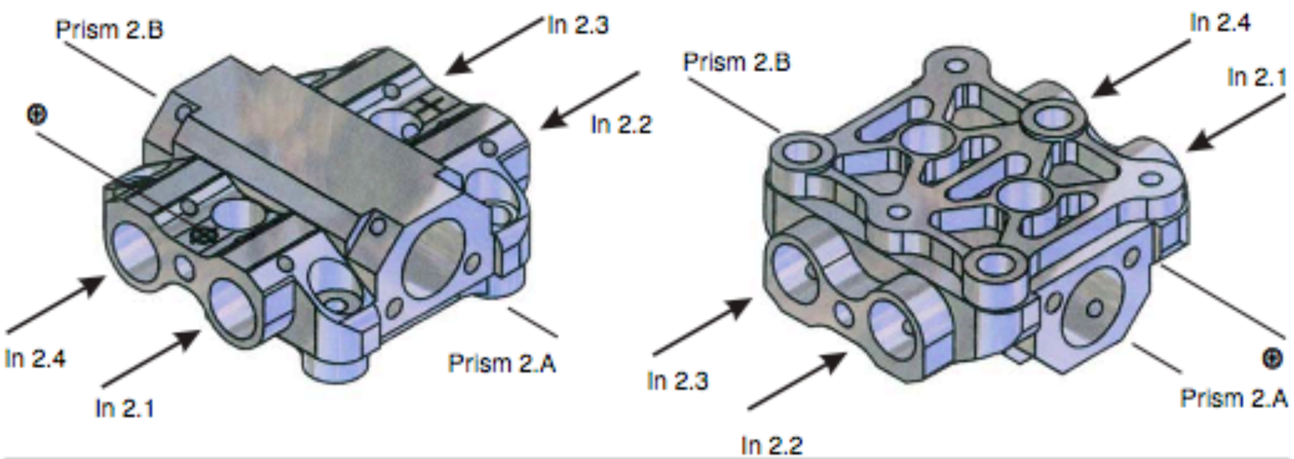
18.04.2007 Schäfter + Kirchhoff

Laser beam port boxes (LBBX)

LBBX Unit 2

Beam Port Box for TAS at AMS-2, RWTH-Aachen

Nomenclature



Fiber Cables

Fiber Type	Corning HI1060, 5.9/125/250 μm
Cable Length	700 mm
Connector Type	Diamond HPC-S0.66/M, Type FC-PC, core-centered < 0.5 μm

Test Fiber Cables

Input Port	Cable Number	Connector Insertion Loss	Connector Return Loss
2.1	B690051100003	-0.16 dB	> 50 dB
2.2	B690051100020	-0.02 dB	> 50 dB
2.3	B690051100021	-0.1 dB	> 50 dB
2.4	B690051100022	-0.05 dB	> 50 dB

Prisms

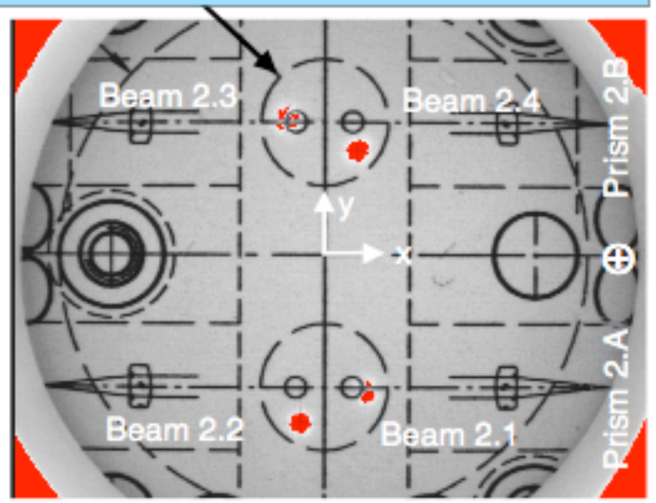
Prism	No
2.A	P9*
2.B	P8*

The asterix denotes if the prism is mount reversly.

Test LBBX: Beam Deviation

Target (1:1 drawing of LBBX housing) with laser spots in 600 mm distance seen in opposit direction to propagation of beams. Mark ⊕ on the right side. Circumcircle 6 mm. Reference for offset is nominal position, respectively.

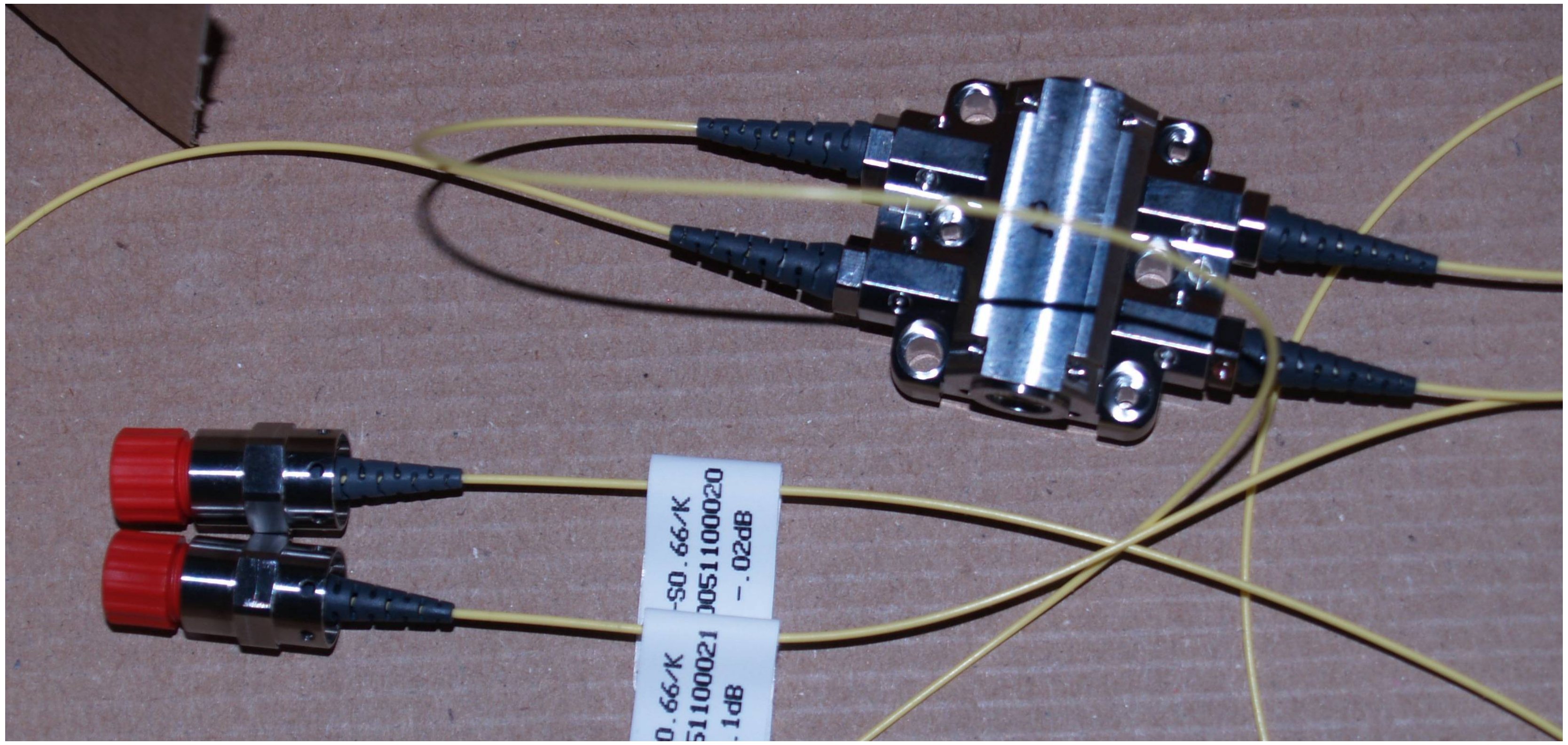
Beam	Offset x [mm]	Offset y [mm]	Angle x [mrad]	Angle y [mrad]
2.1	3.29	-0.23	5.48	-0.38
2.2	-2.50	-1.68	-4.16	-2.80
2.3	-3.11	0.15	-5.19	0.25
2.4	2.88	-1.36	4.81	-2.26

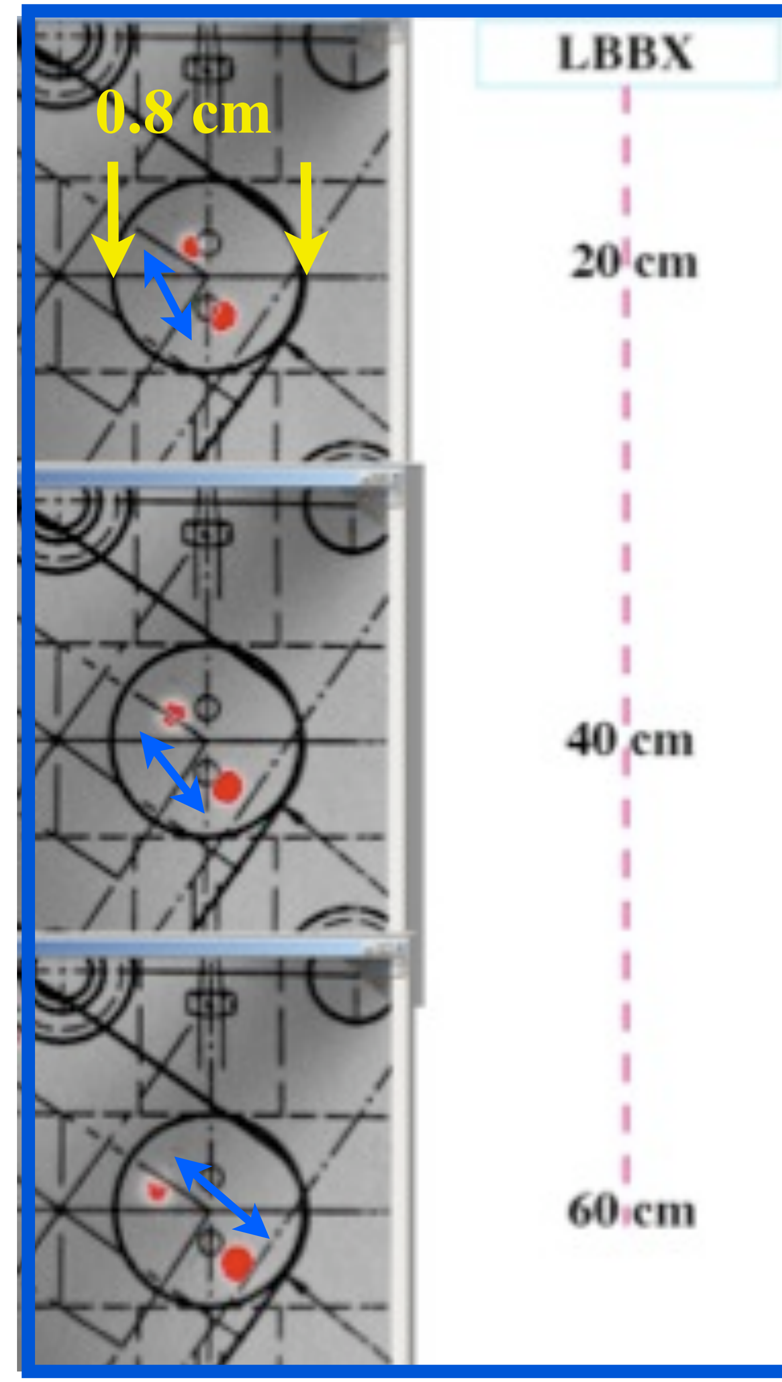


Protokoll_LBBX.rtd Unit 2

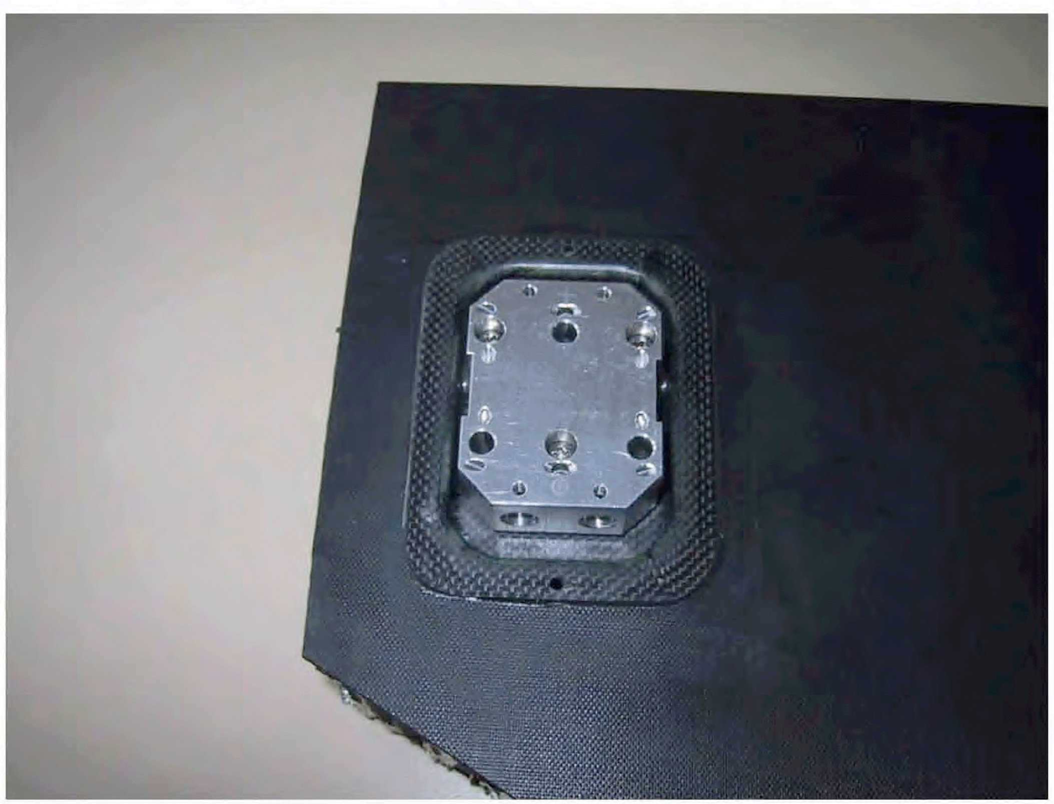
Schäfter + Kirchhoff GmbH
Kieler Straße 212, D-22525 Hamburg - Tel: +49 (0)40 853 997 0 - Fax: +49 (0)40 853 997 79 - eMail: info@SuKHamburg.de - Web: http://www.SuKHamburg.de

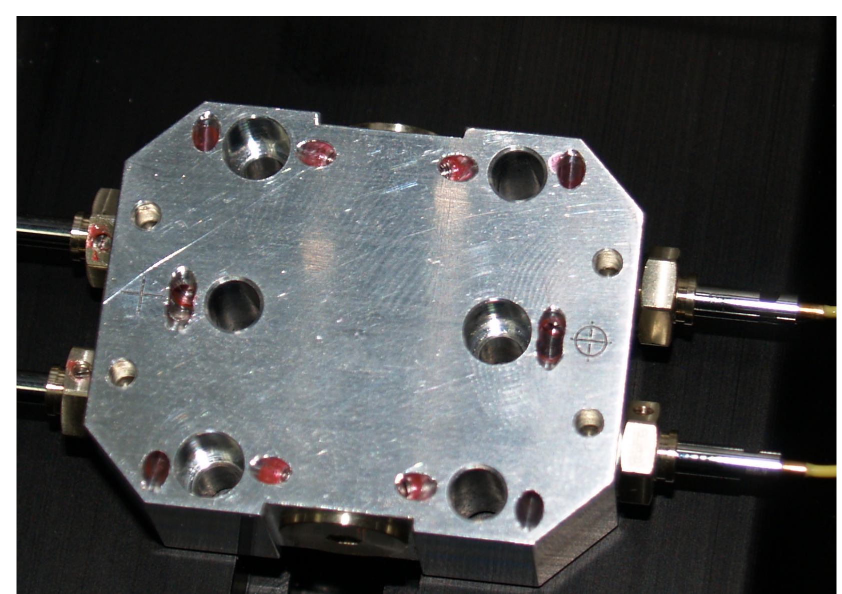
Laser beam port boxes (LBBX)





Beamport box (without optics) mounted in a CFC pocket in plate 1 (specimen)





Laser beam port boxes (LBBX)

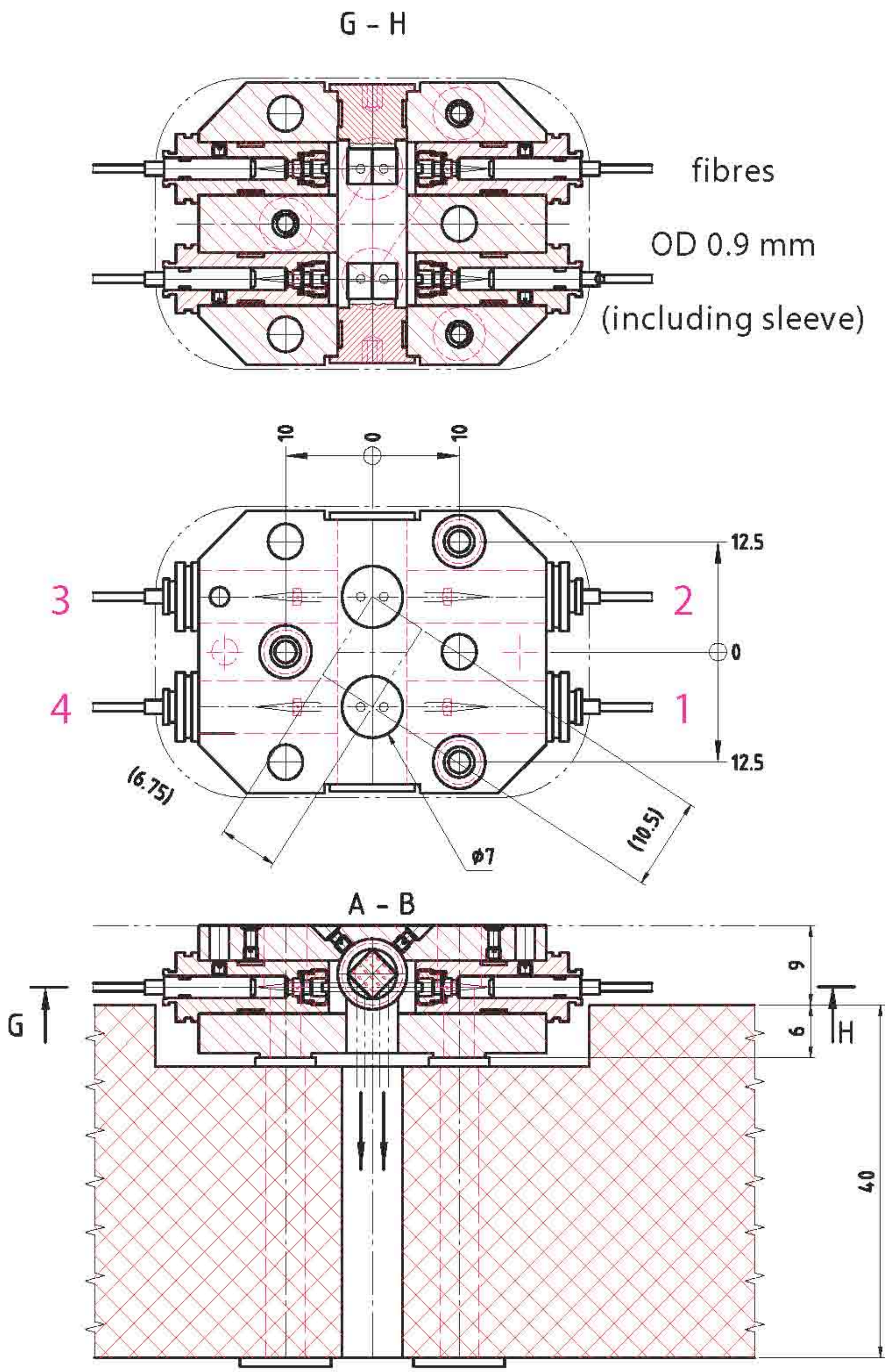
Fig. 3 of 9

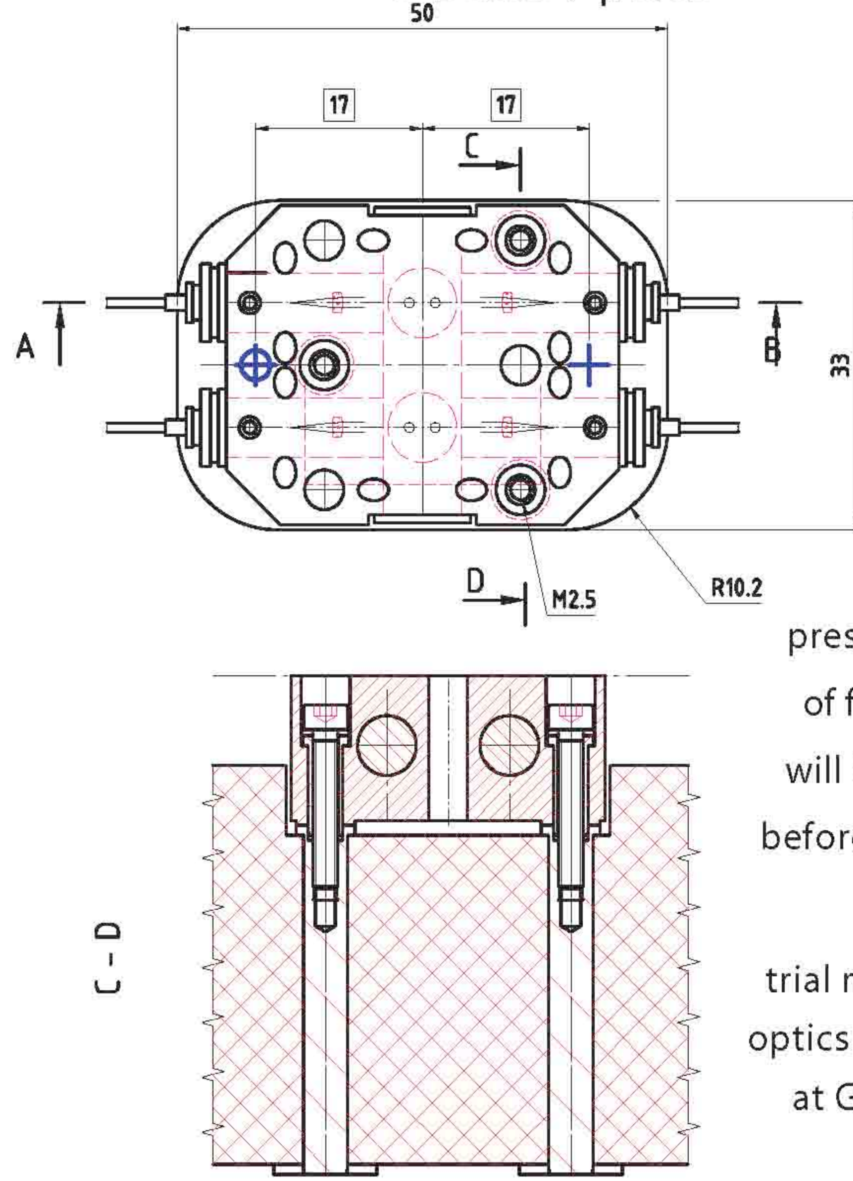
AMS TAS beamport boxes

4 fibres each

mounted on outer tracker plates (1, 5)

5 boxes / plate





preseries (QMII)

of flight boxes

will be delivered

before Jan 31, 2005

trial mounting and

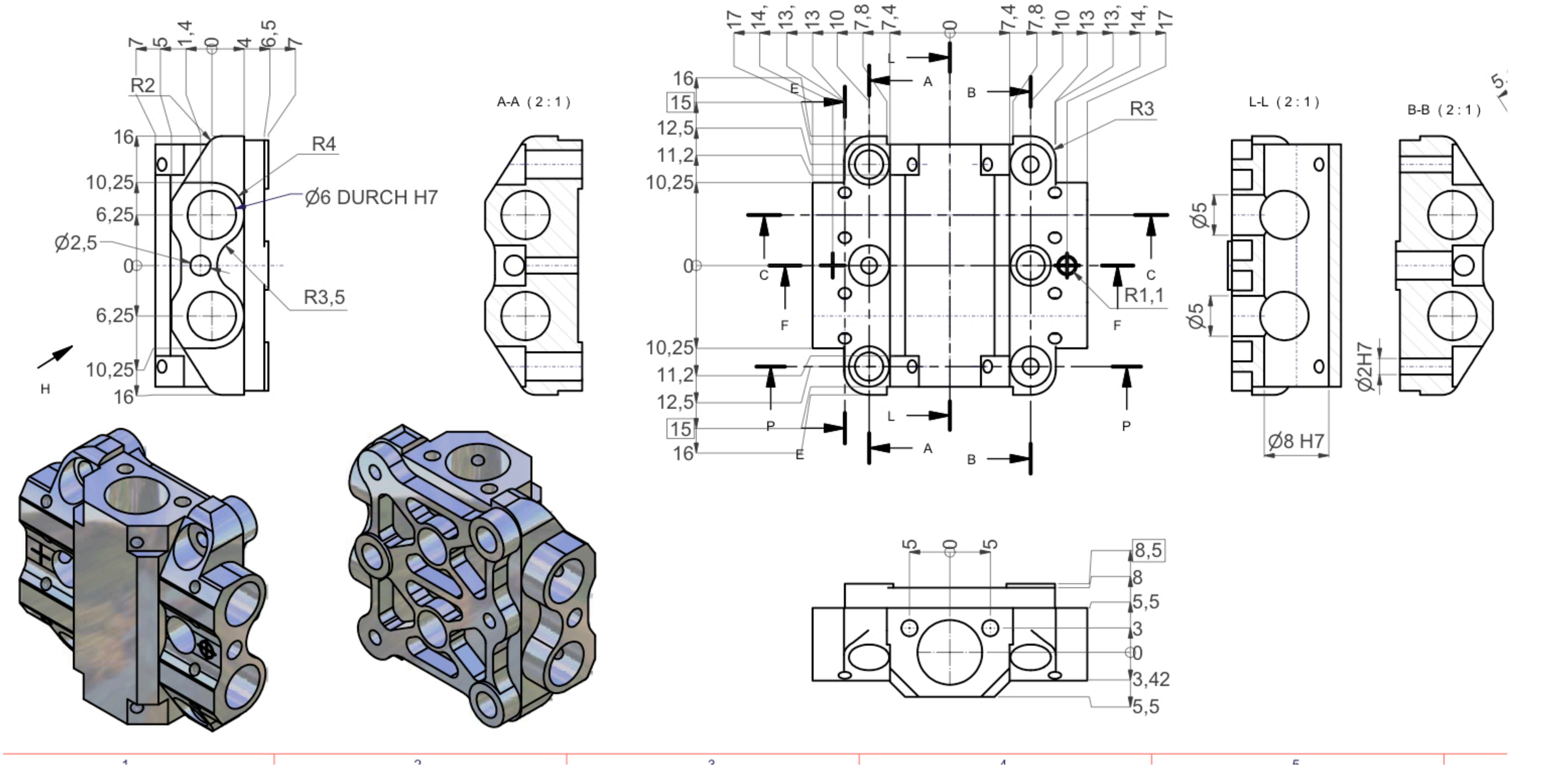
optics test on plate 1

at GVA planned

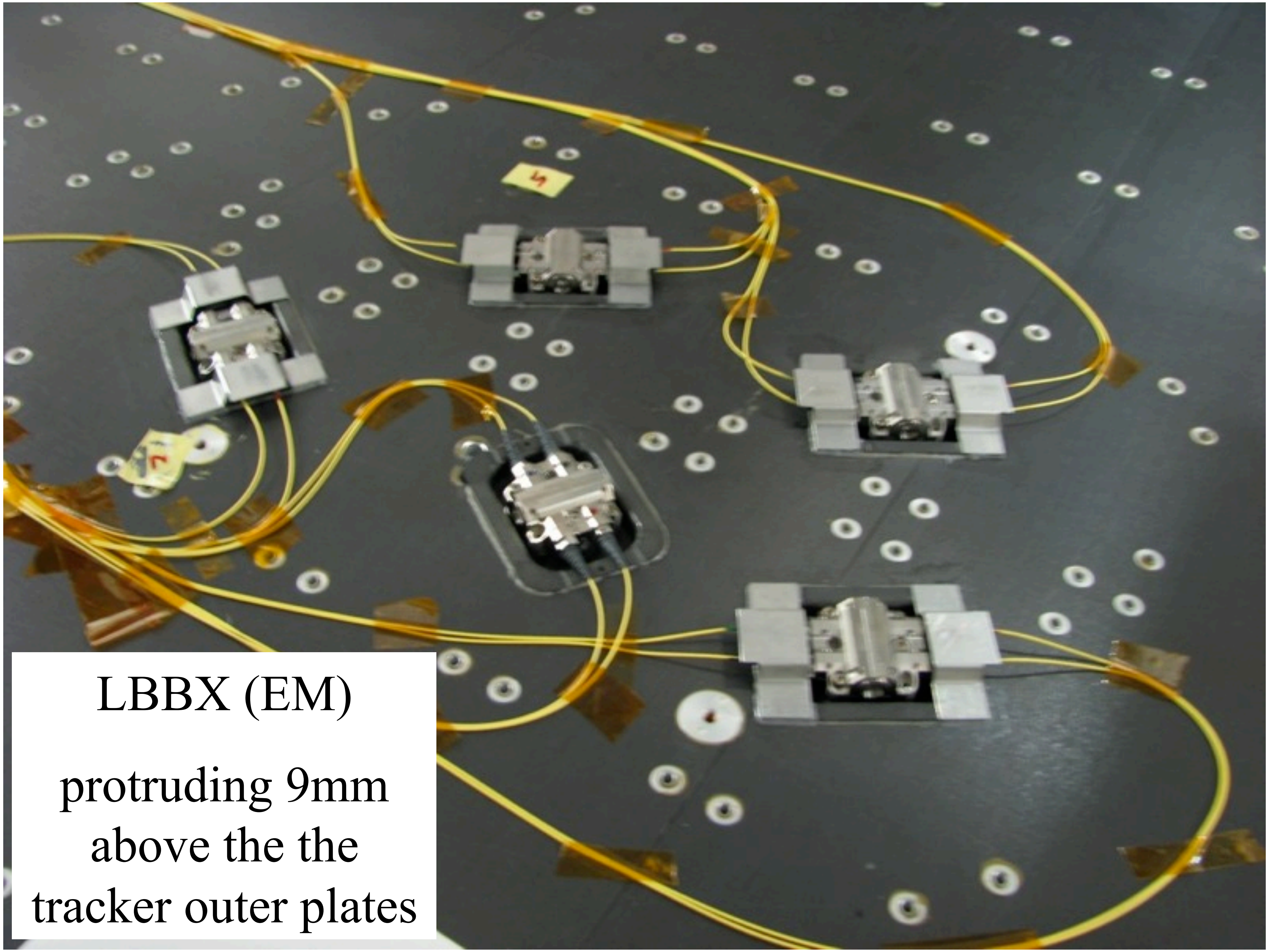
W. Wallraff AMS RWTH-AAchen

2004-12-05

Laser beam port boxes (LBBX)



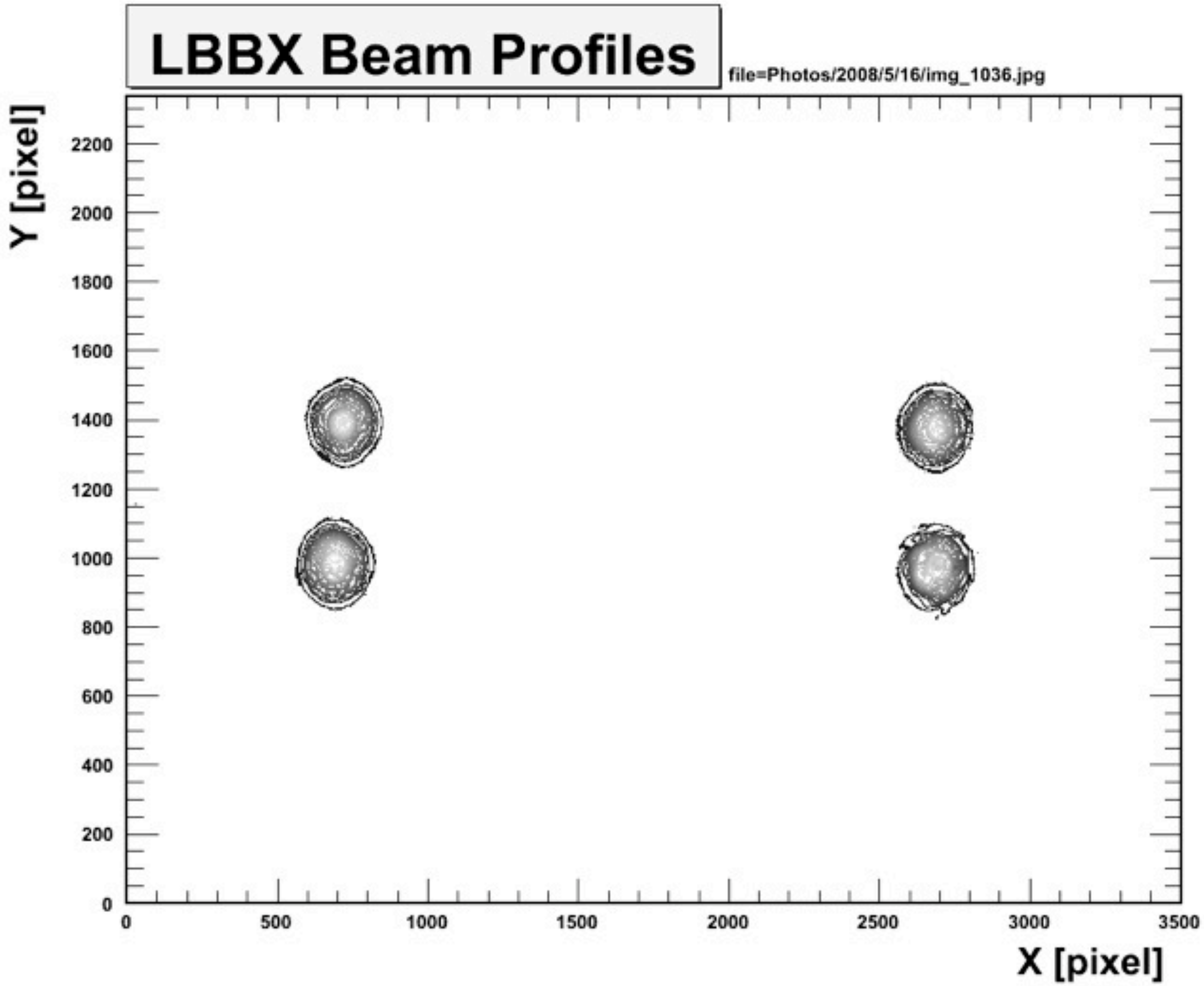
LBBX on the outer Tracker Plane



LBBX (EM)

protruding 9mm above the the tracker outer plates

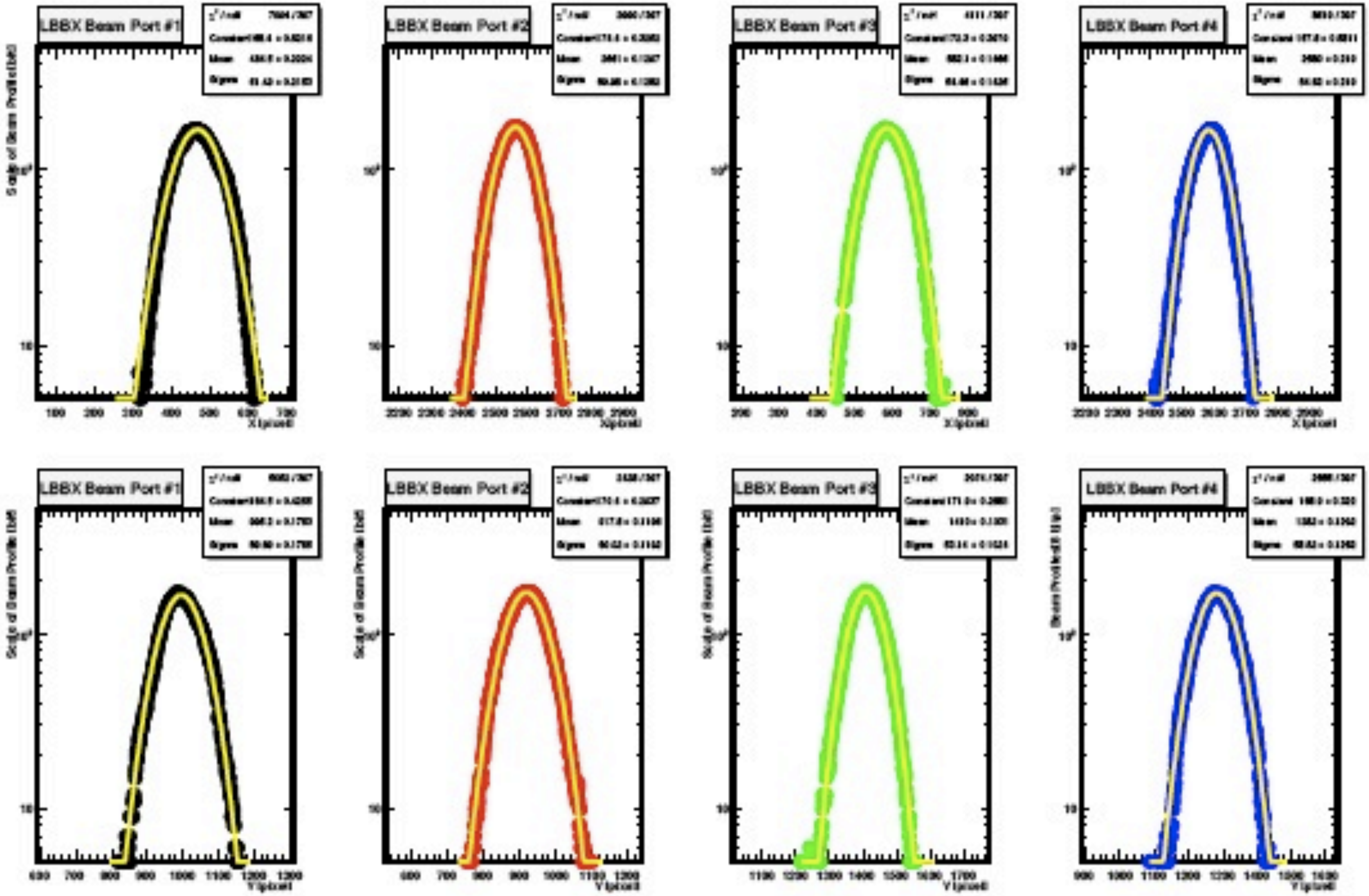
LBBXs Functionality Test



Laser Current = 30 mA
CCD Resolution = 6.42 um/pixel

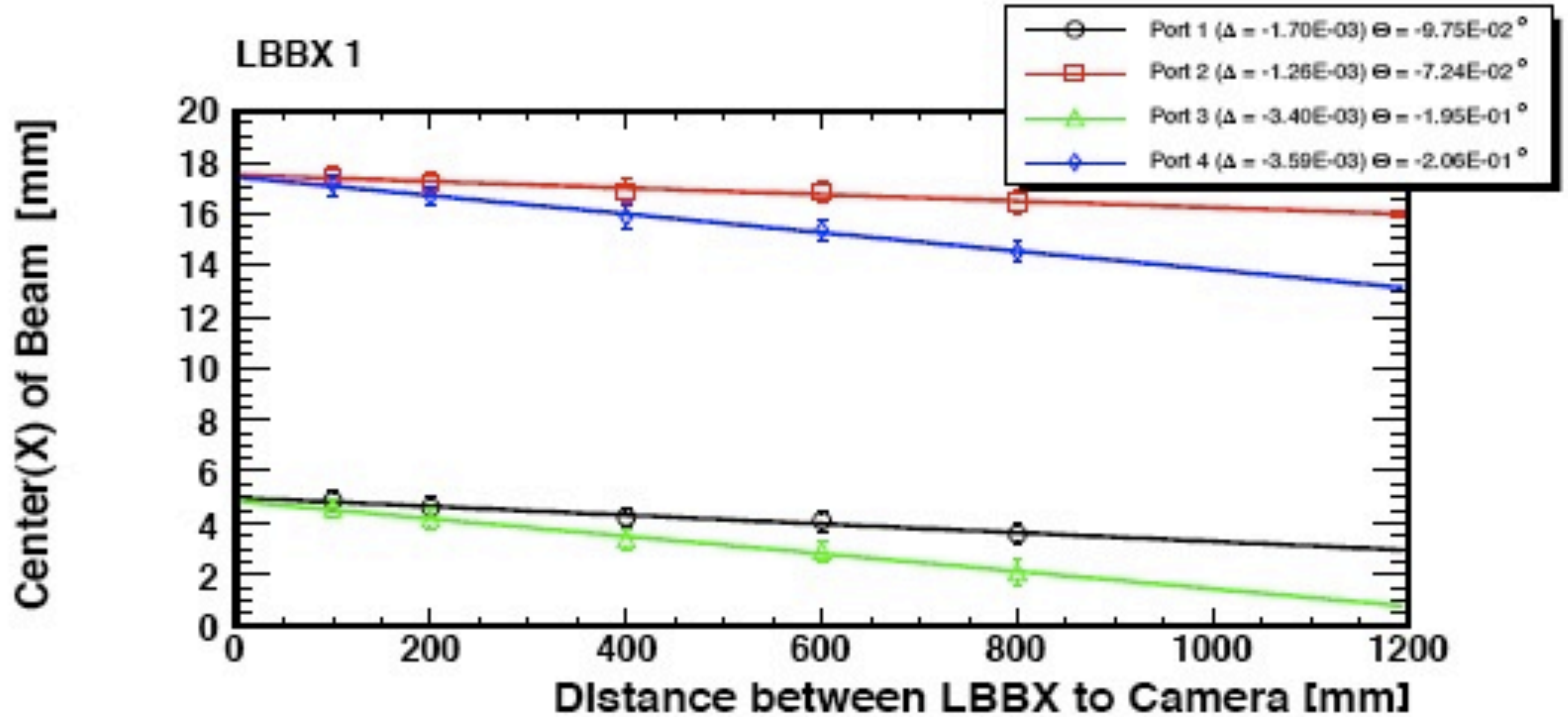
LBBX#4: Laser beam profiles at the distance of 10 cm

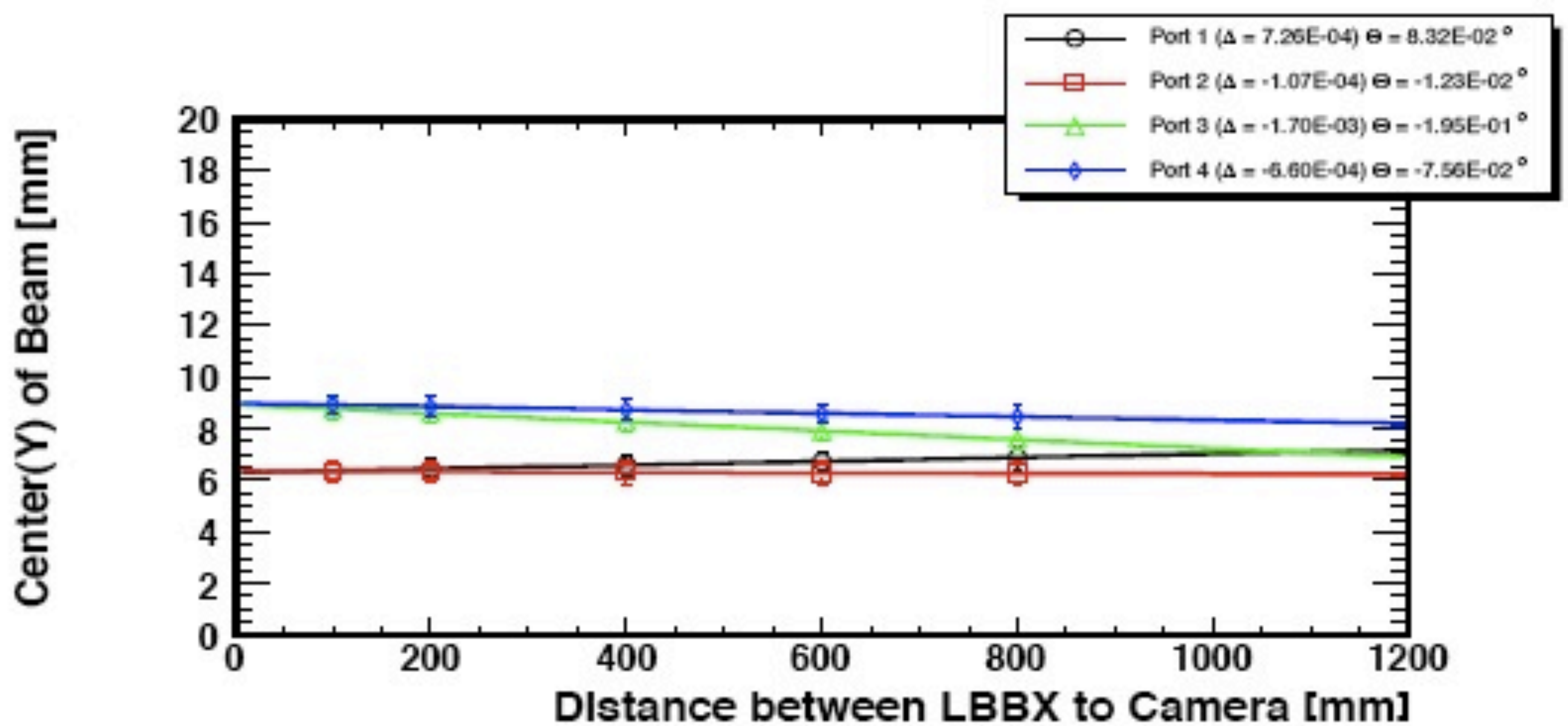
Beam profiles in CCD

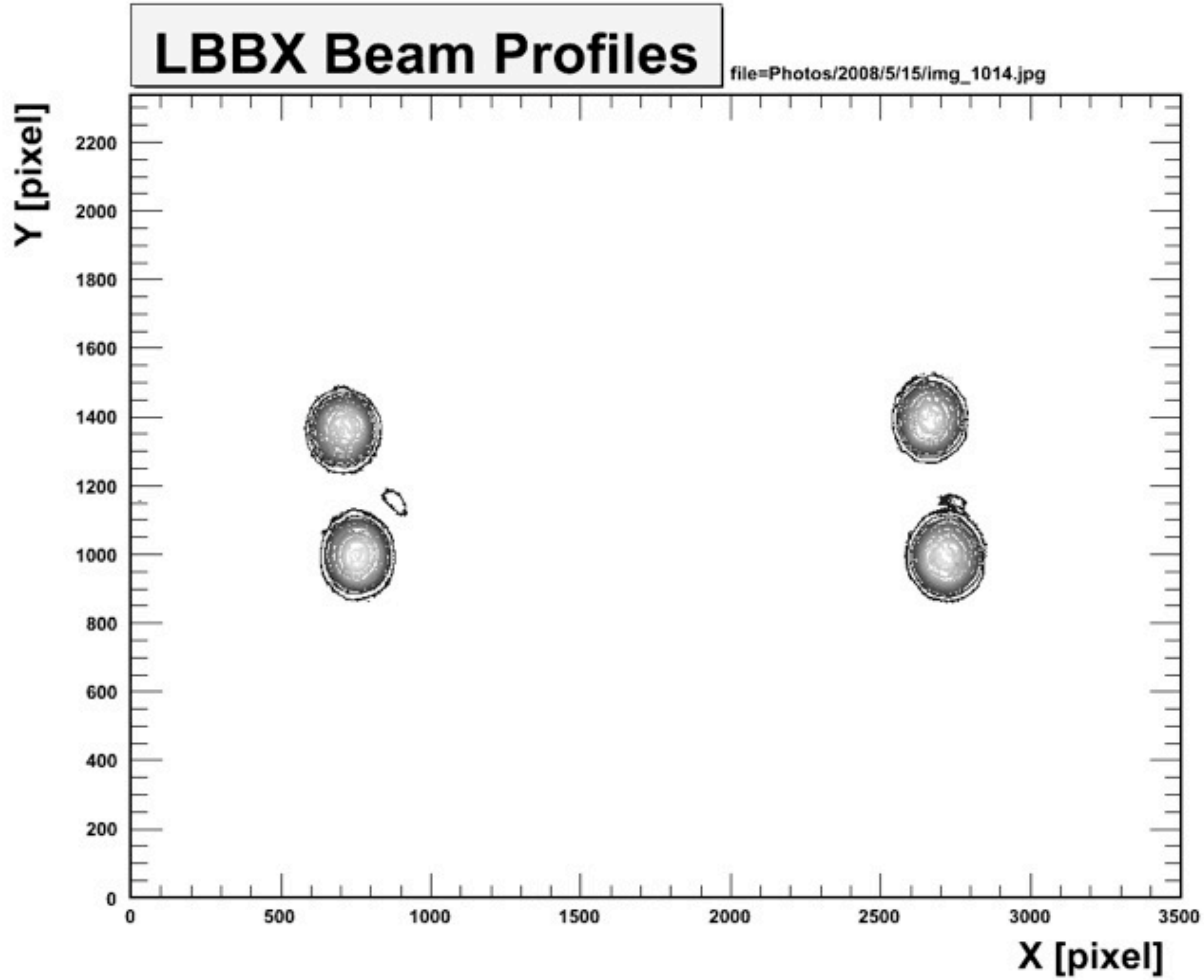


LBBX#4: Laser beam profiles at the distance of 10 cm

Position of beam center



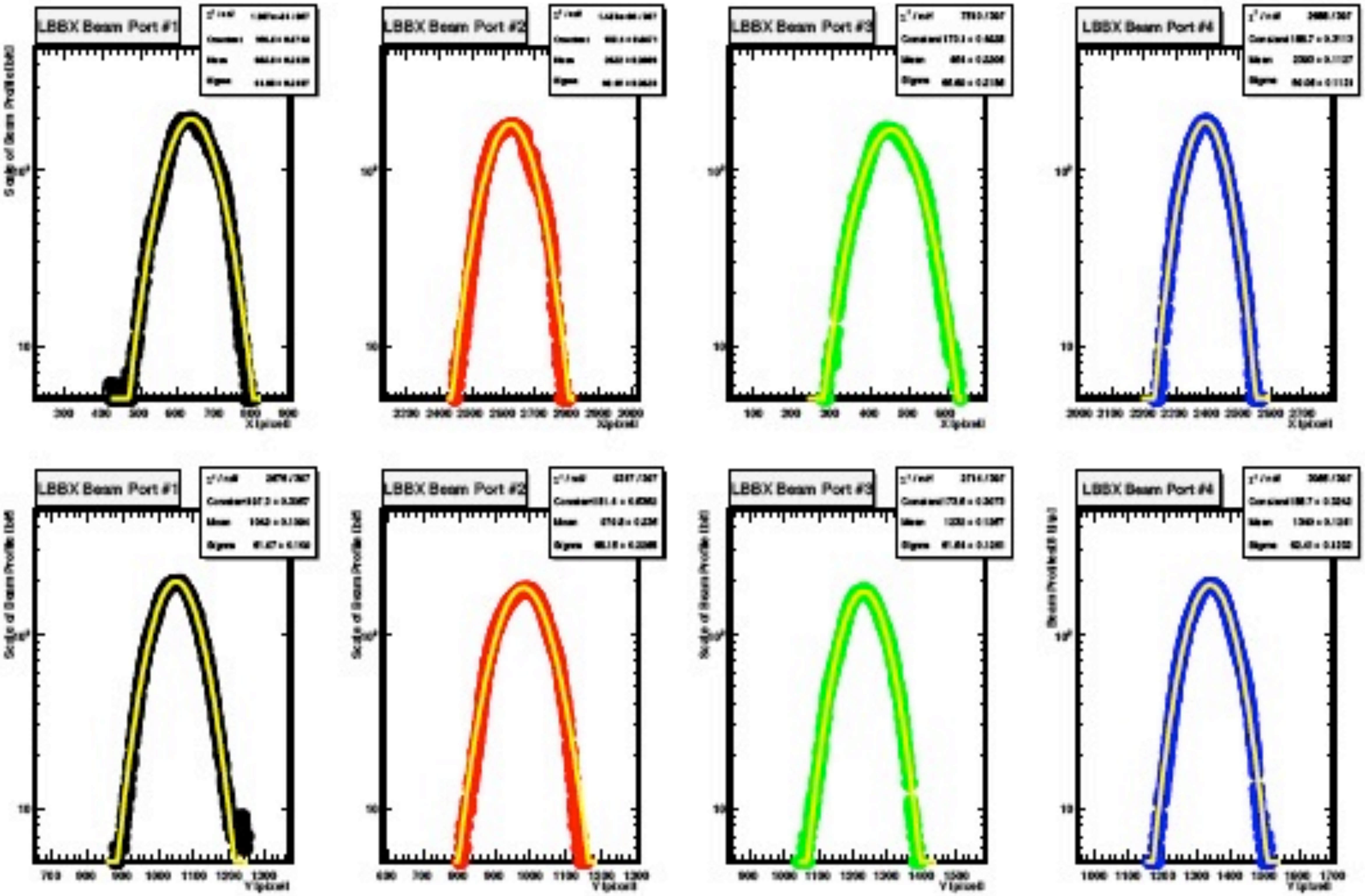




Laser Current = 30 mA
CCD Resolution = 6.42 um/pixel

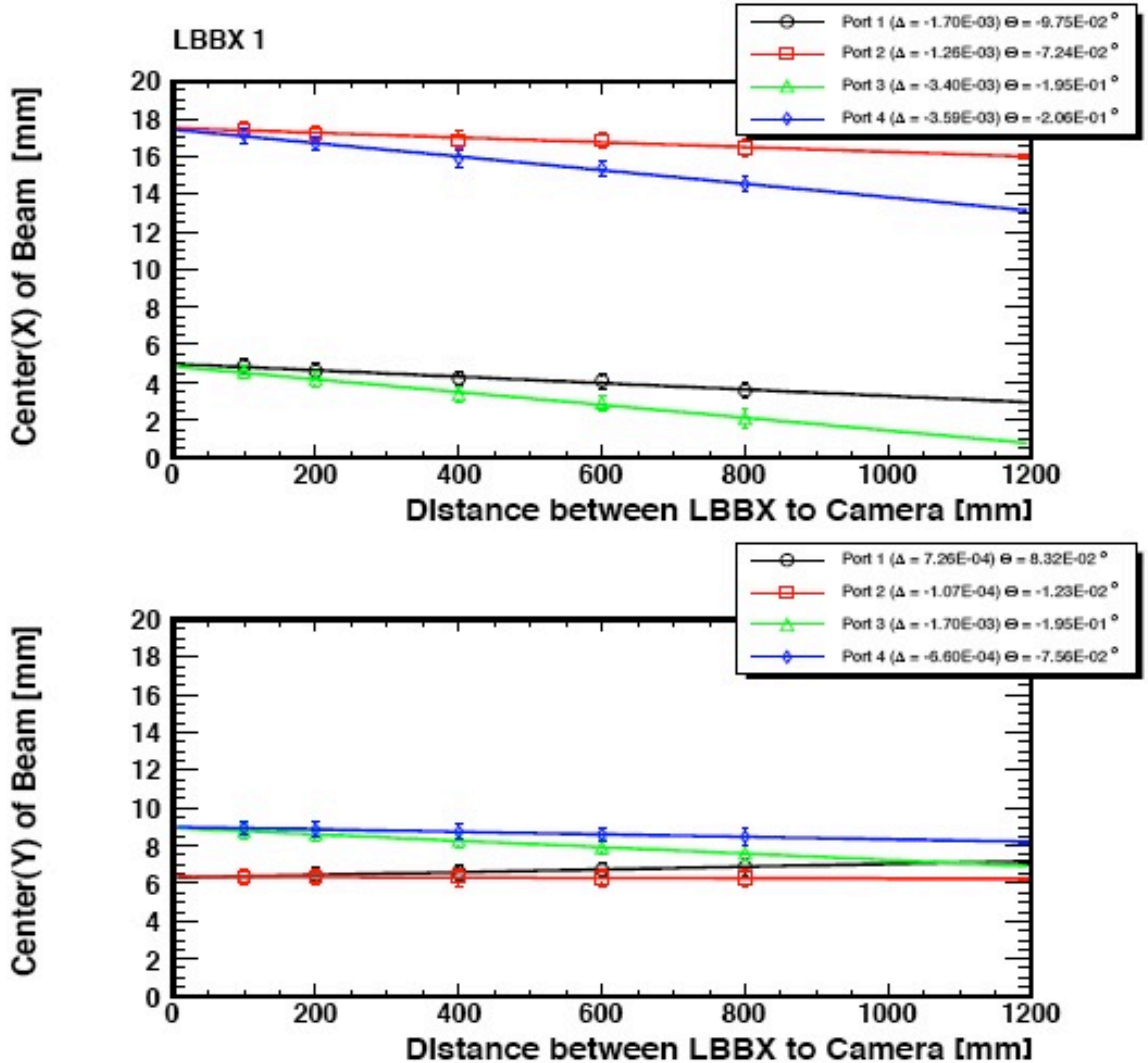
LBBX#1: Laser beam profiles at the distance of 10 cm

Beam profiles in CCD



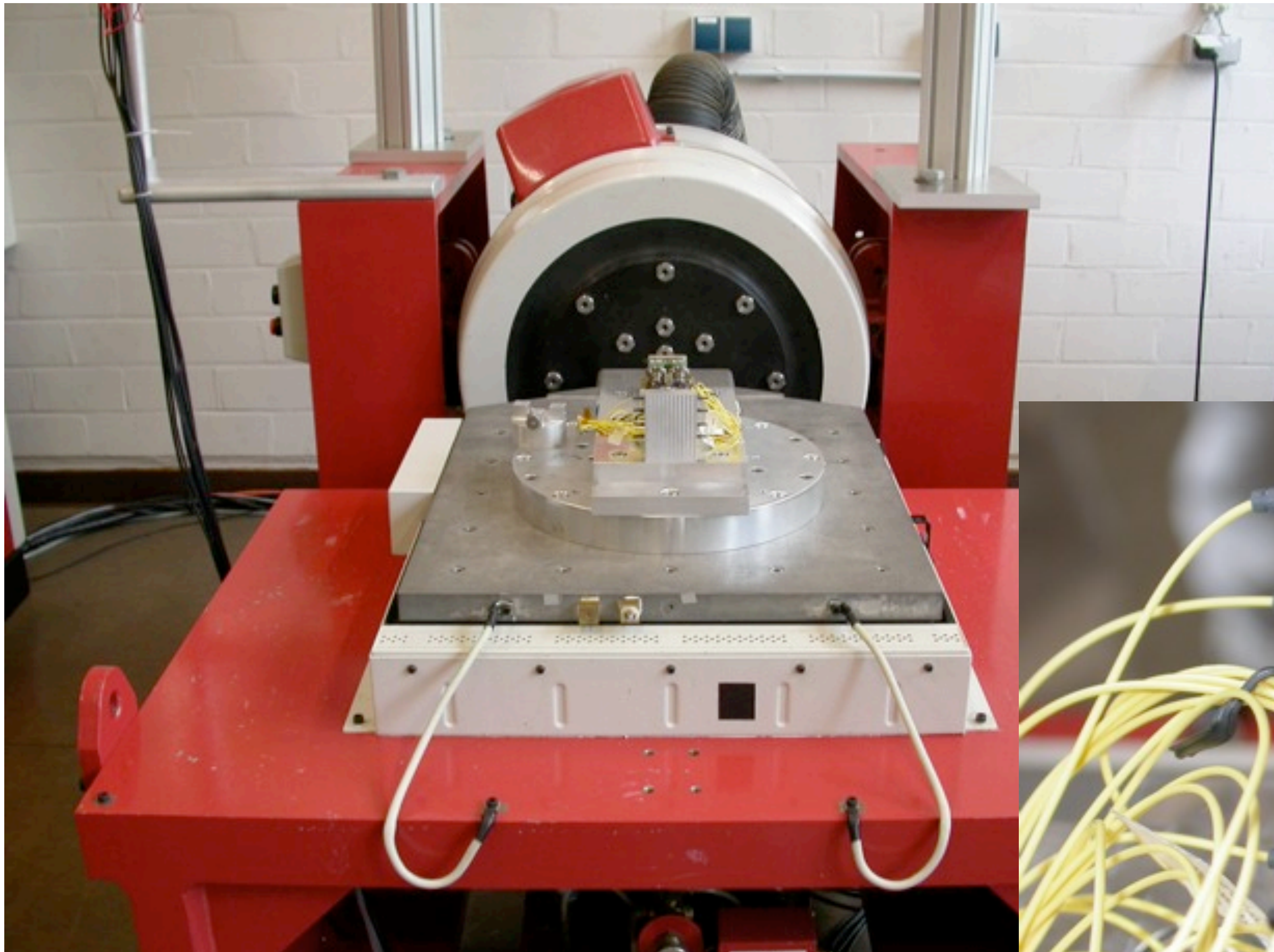
Beam Width = 60 pixel x 6.42 um/pixel = 350 um

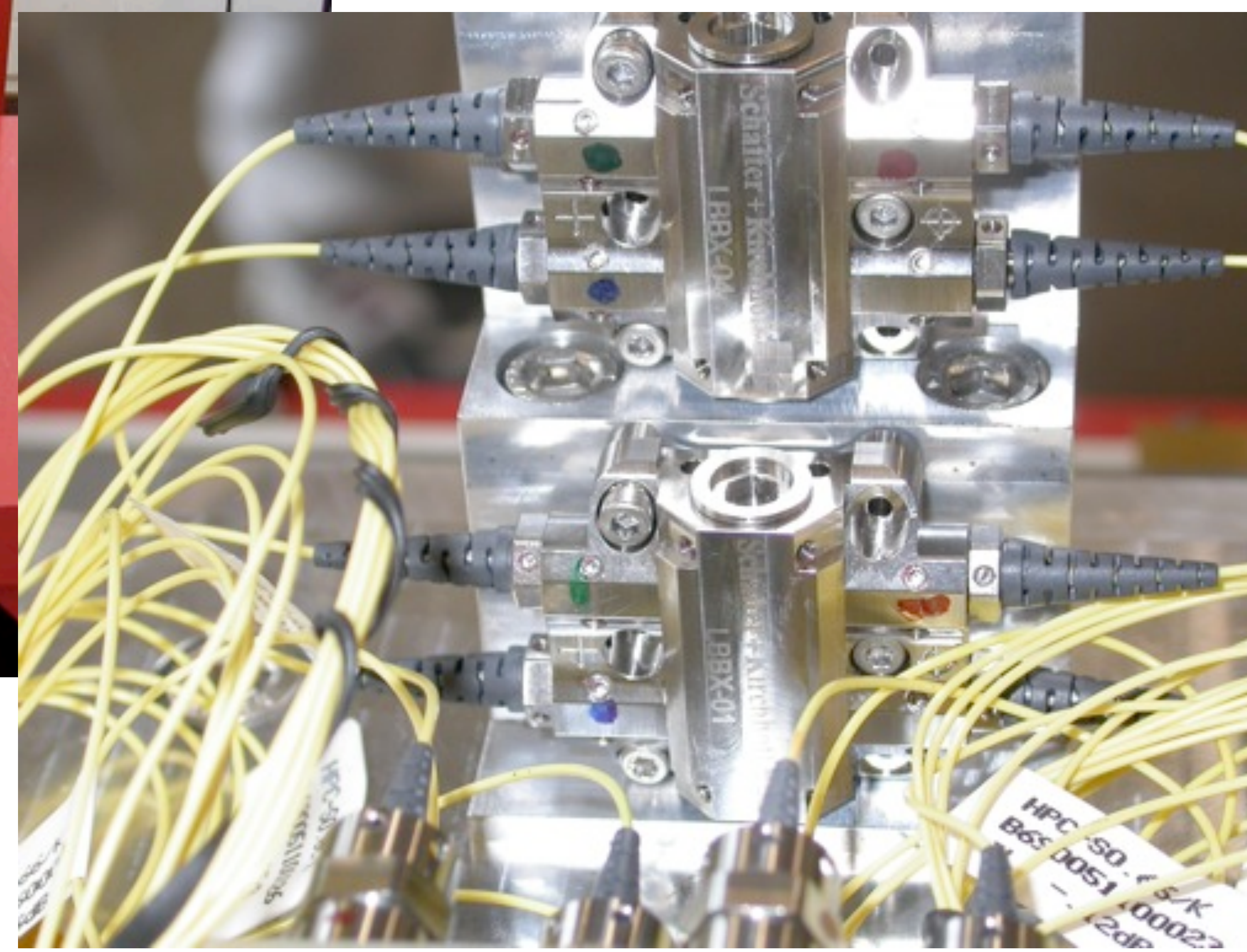
Position of beam center



LBBXs Space Qualification Test (19/06/2008)

LBBX: Vibration Setup





LBBX Unit#1 and Unit #4: Passive Vibration (6.8 g, X-Y-Z direction)

TVT Set-up

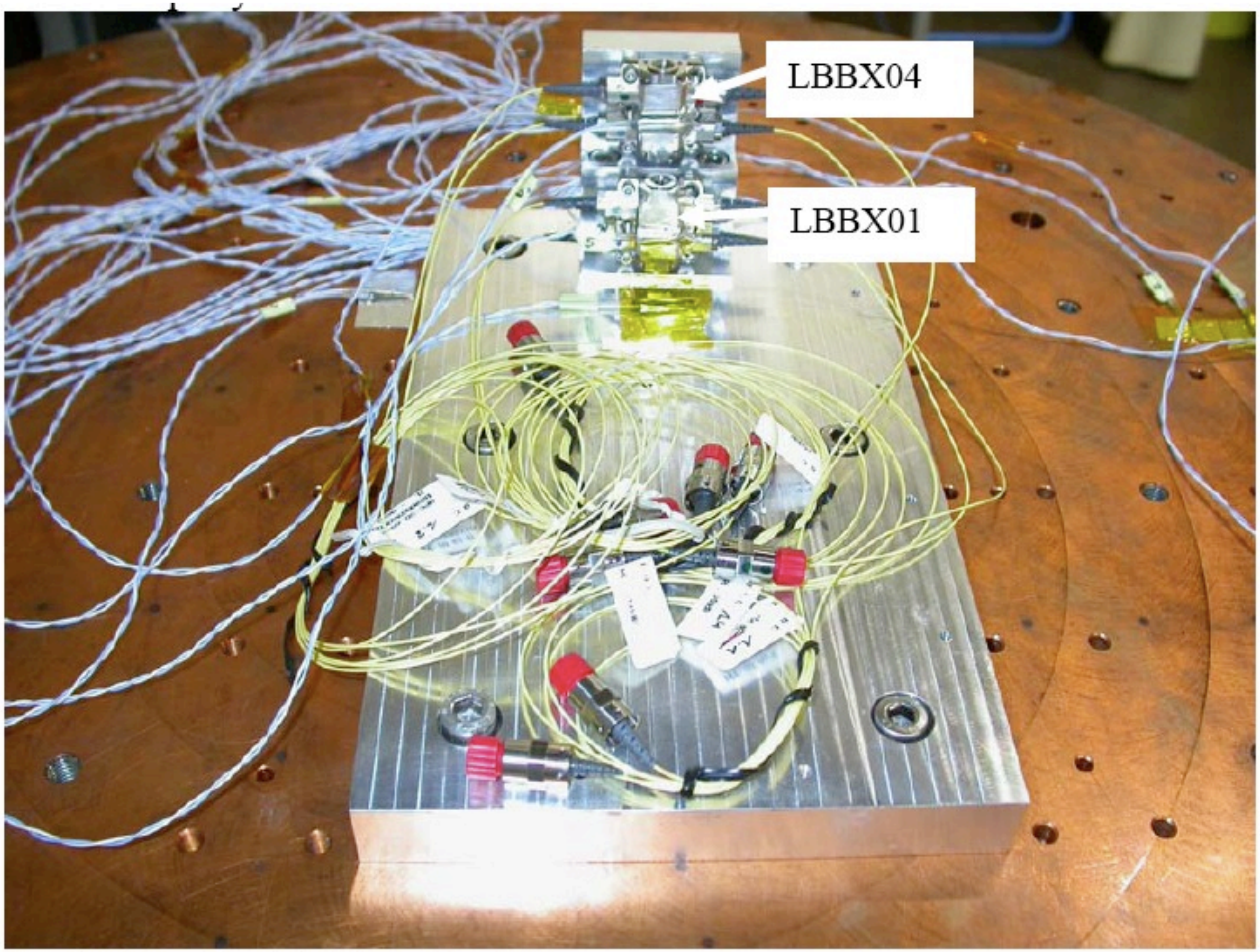


Fig. 2 TVT setup LBBX on aluminium

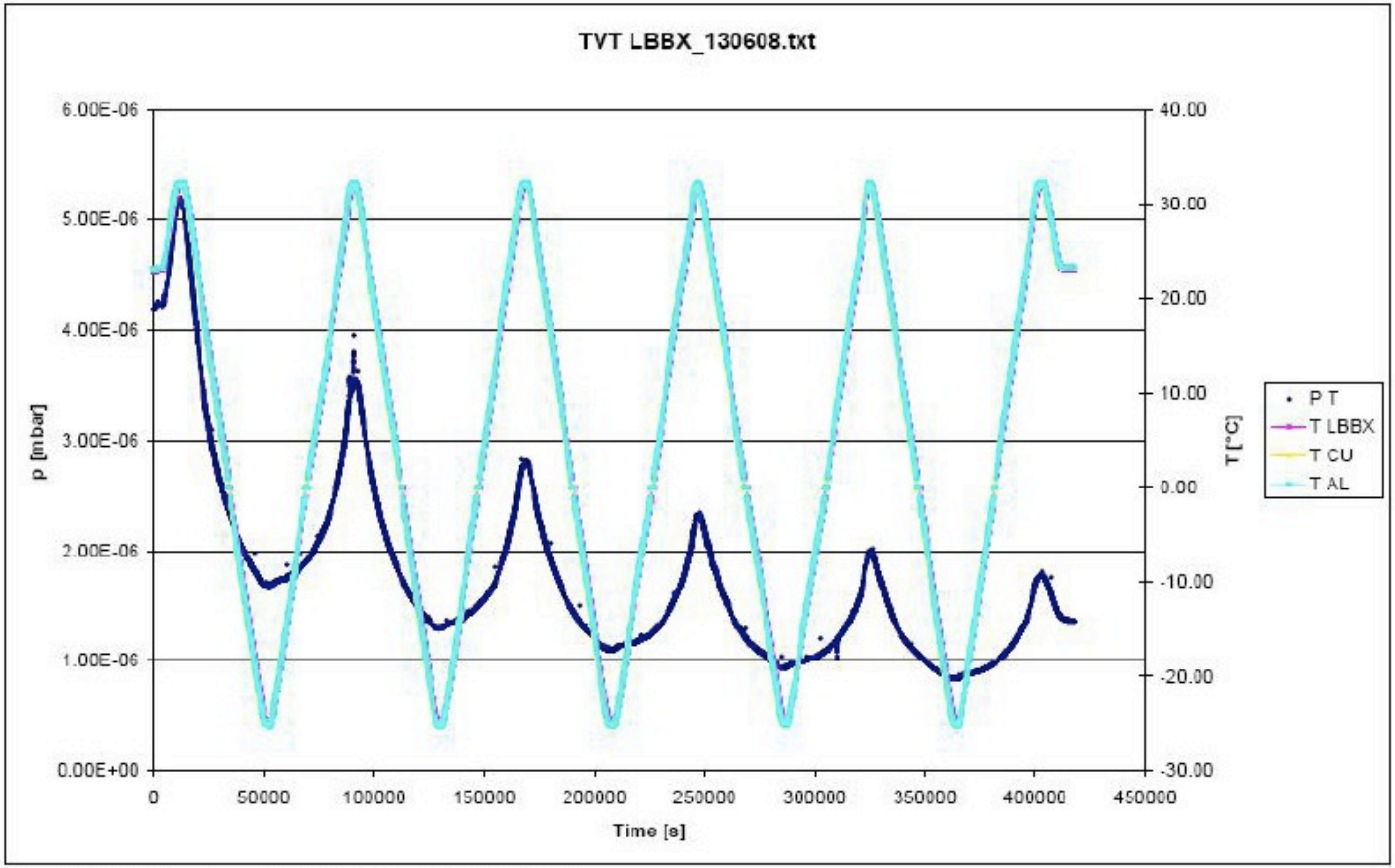
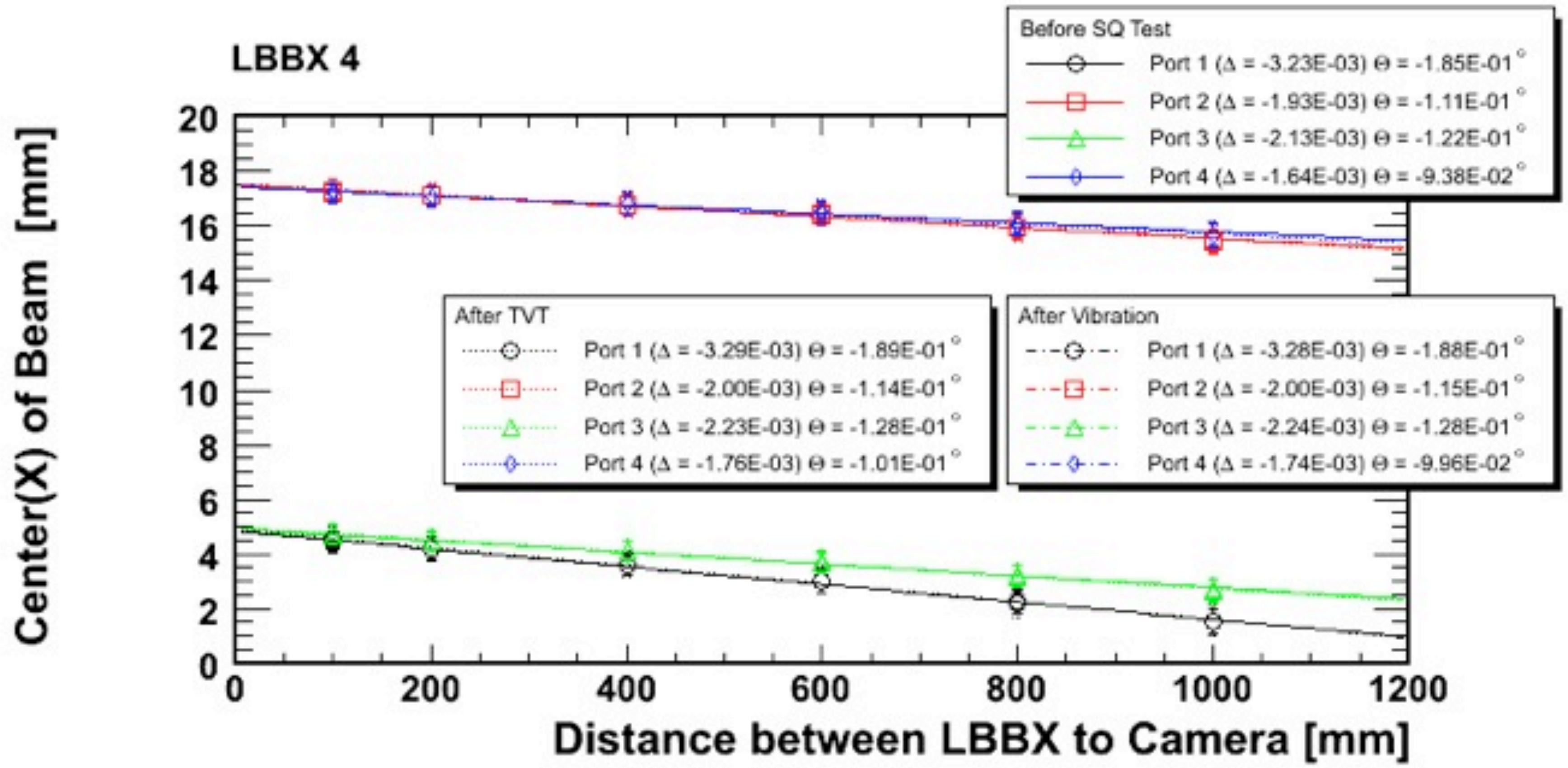
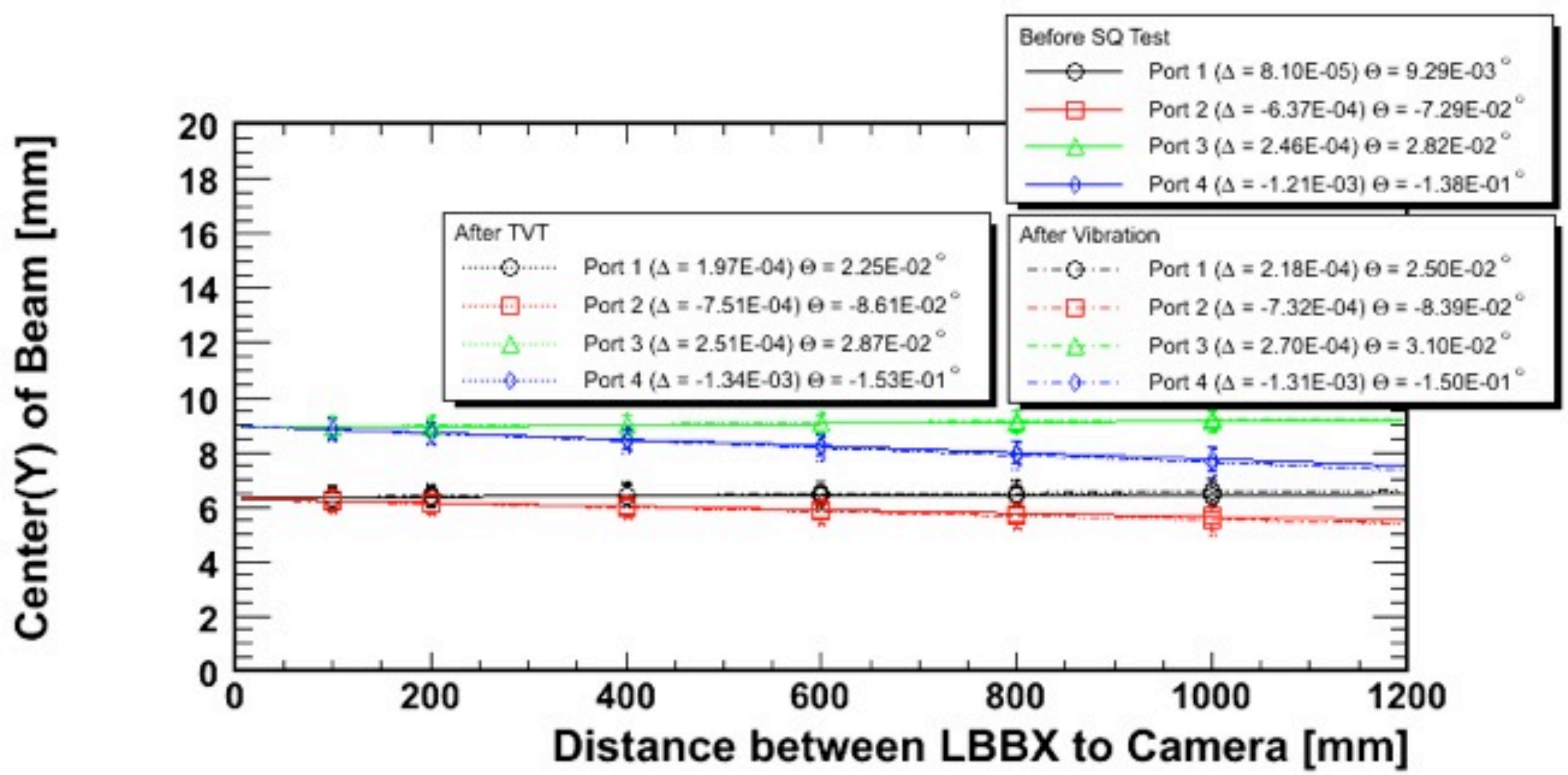


Fig. 1 TVT setup LBBX01 & LBBX04

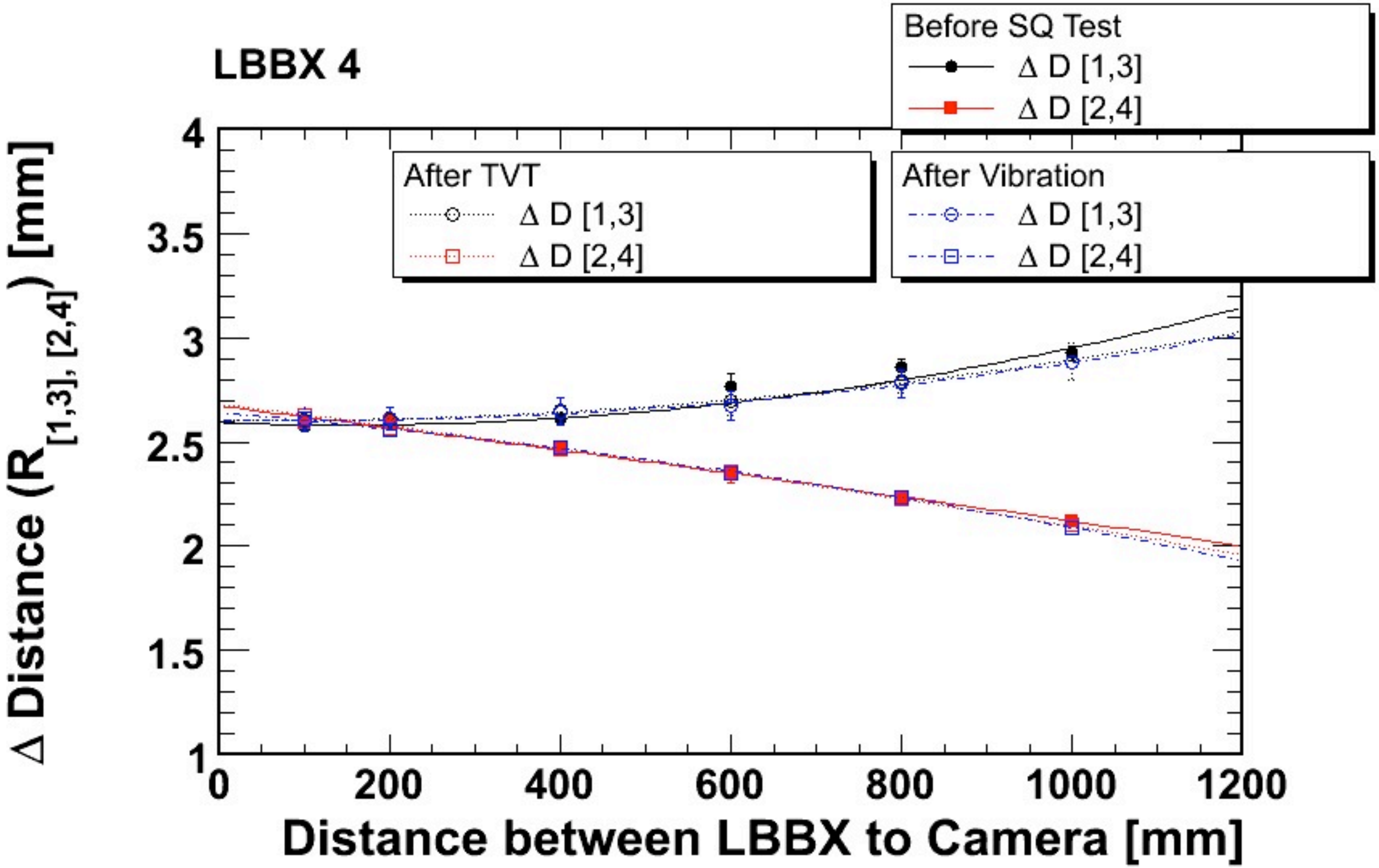
P T = pressure in tank
T CU = Temperature on copper plate
T AL = T aluminium
T LBBX = T LBBX01

Position of beam center



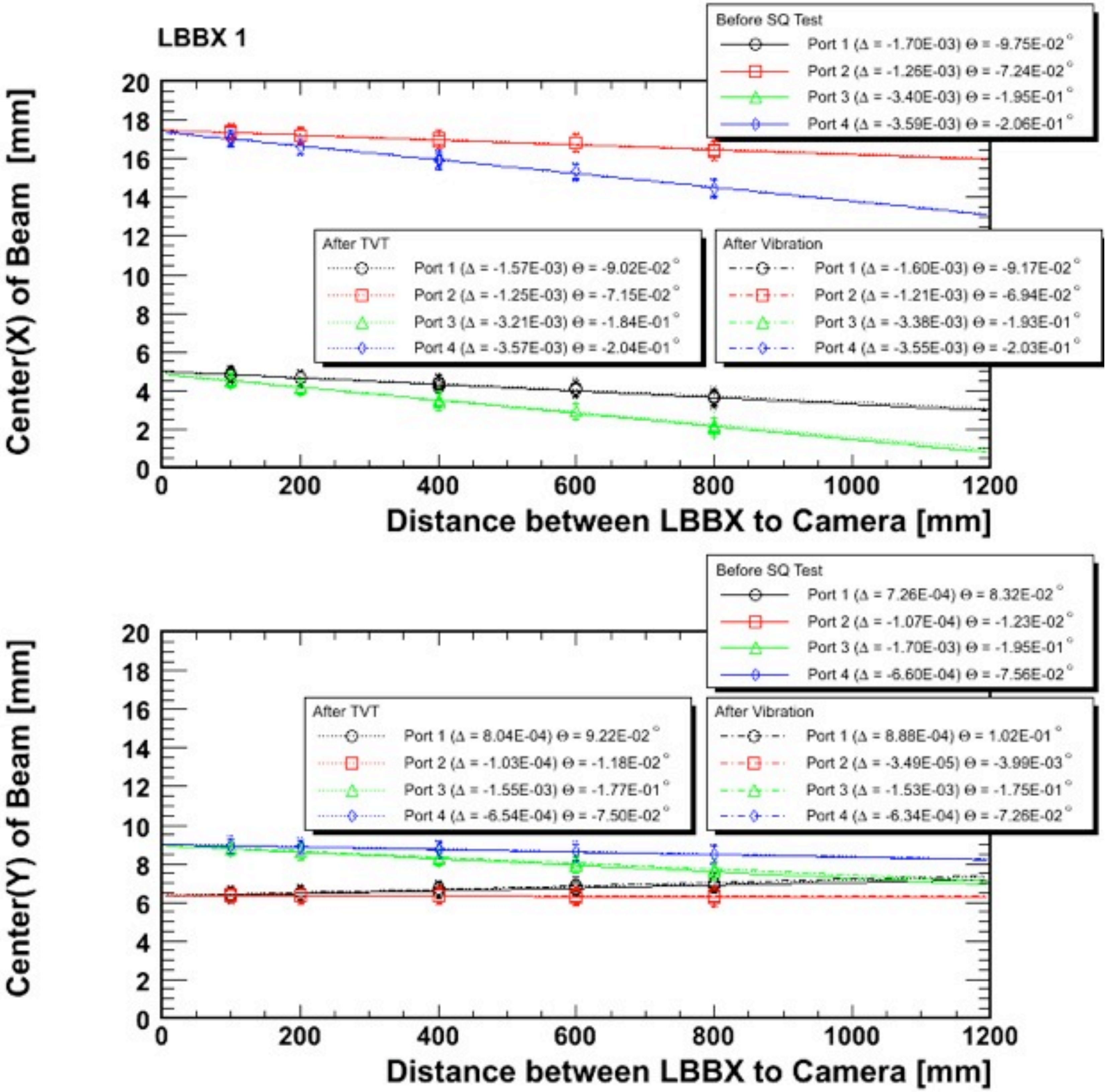


Distance of beam center in pairs

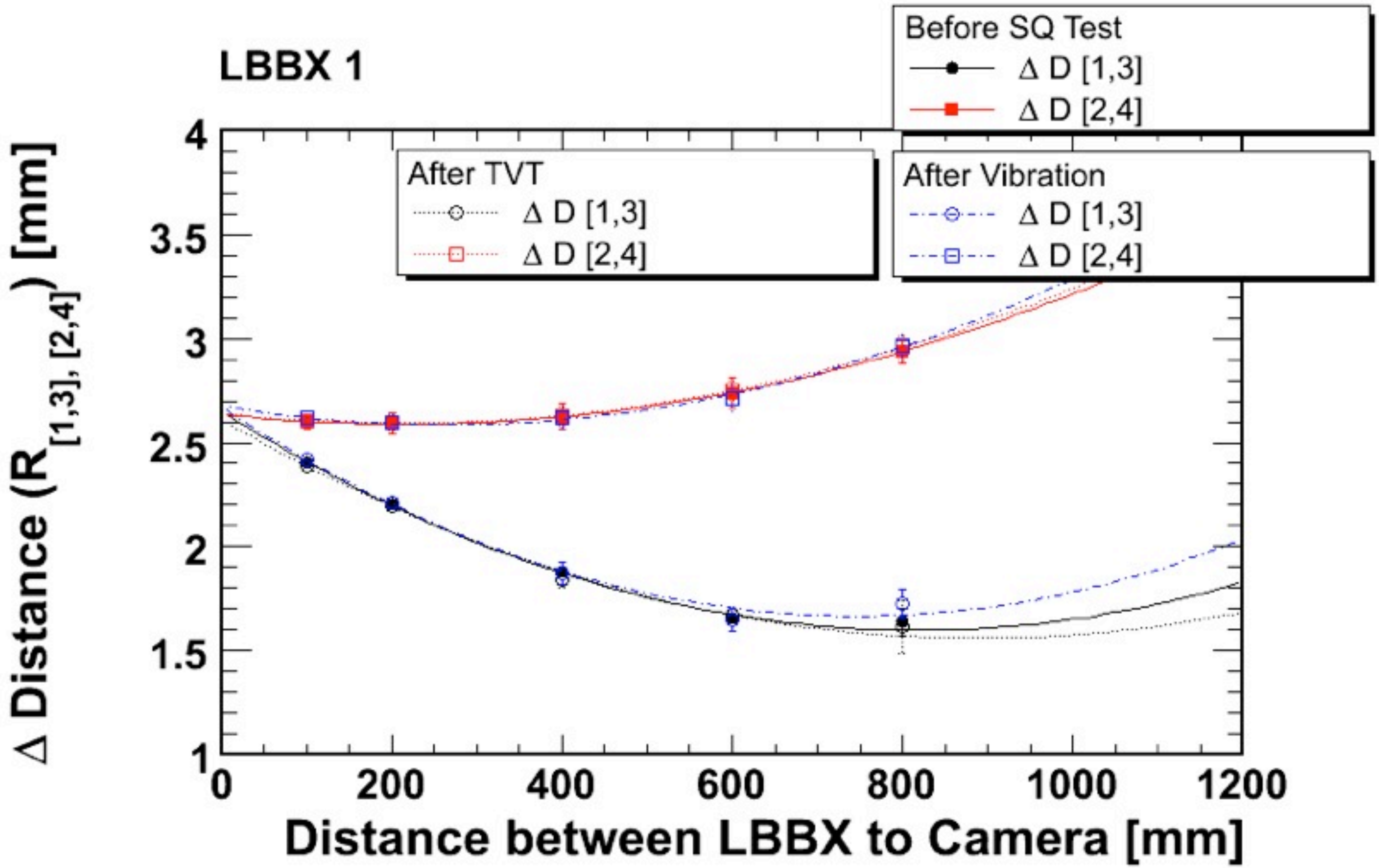


No damage/degradation of LBBX Unit #4 from a series of SQT

Position of beam center



Distance of beam center in pairs



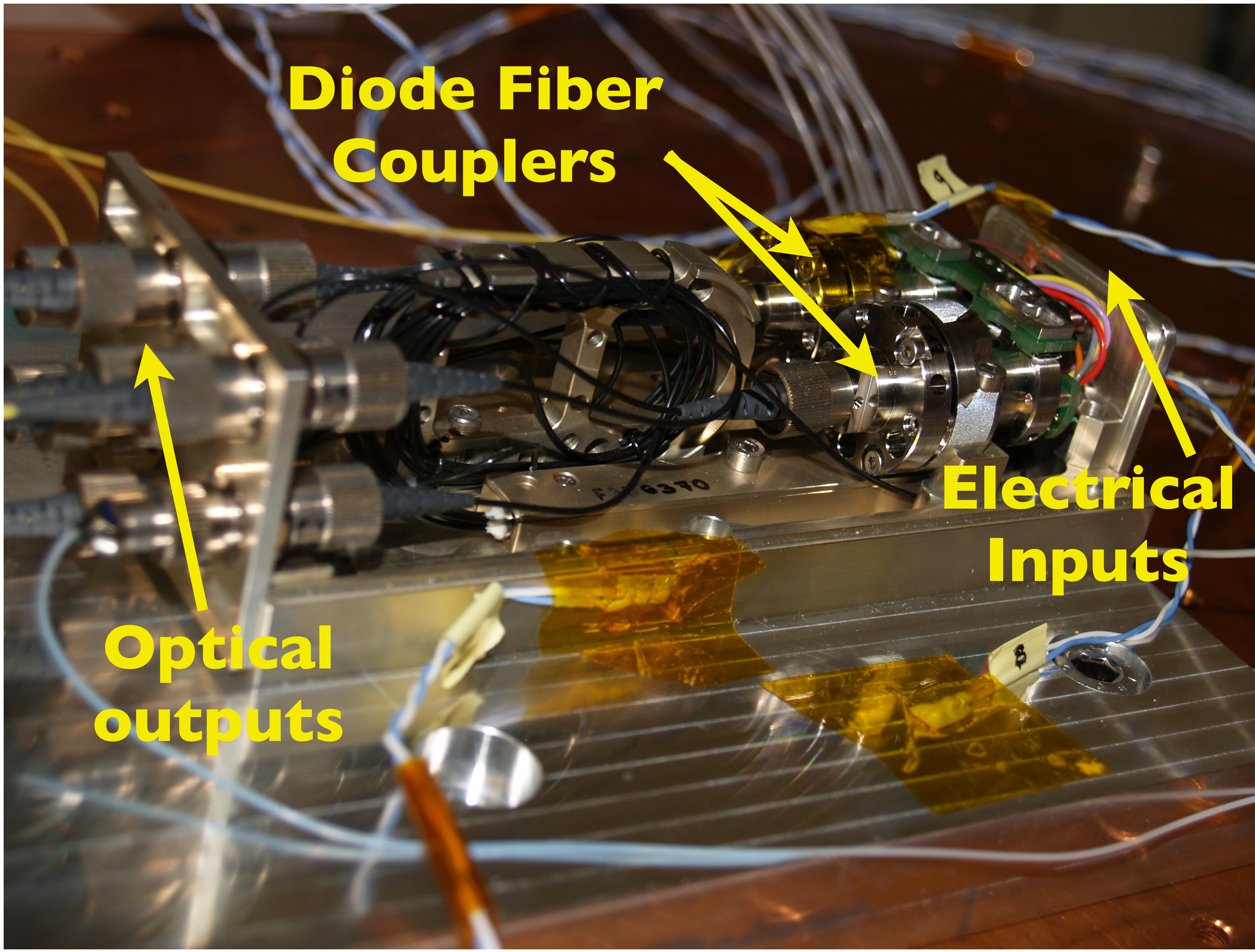
No damage/degradation of LBBX Unit #1 from a series of SQT

AMS-02 TAS

Laser Fiber Coupler (LFCR)

(see tests at the end of this document)

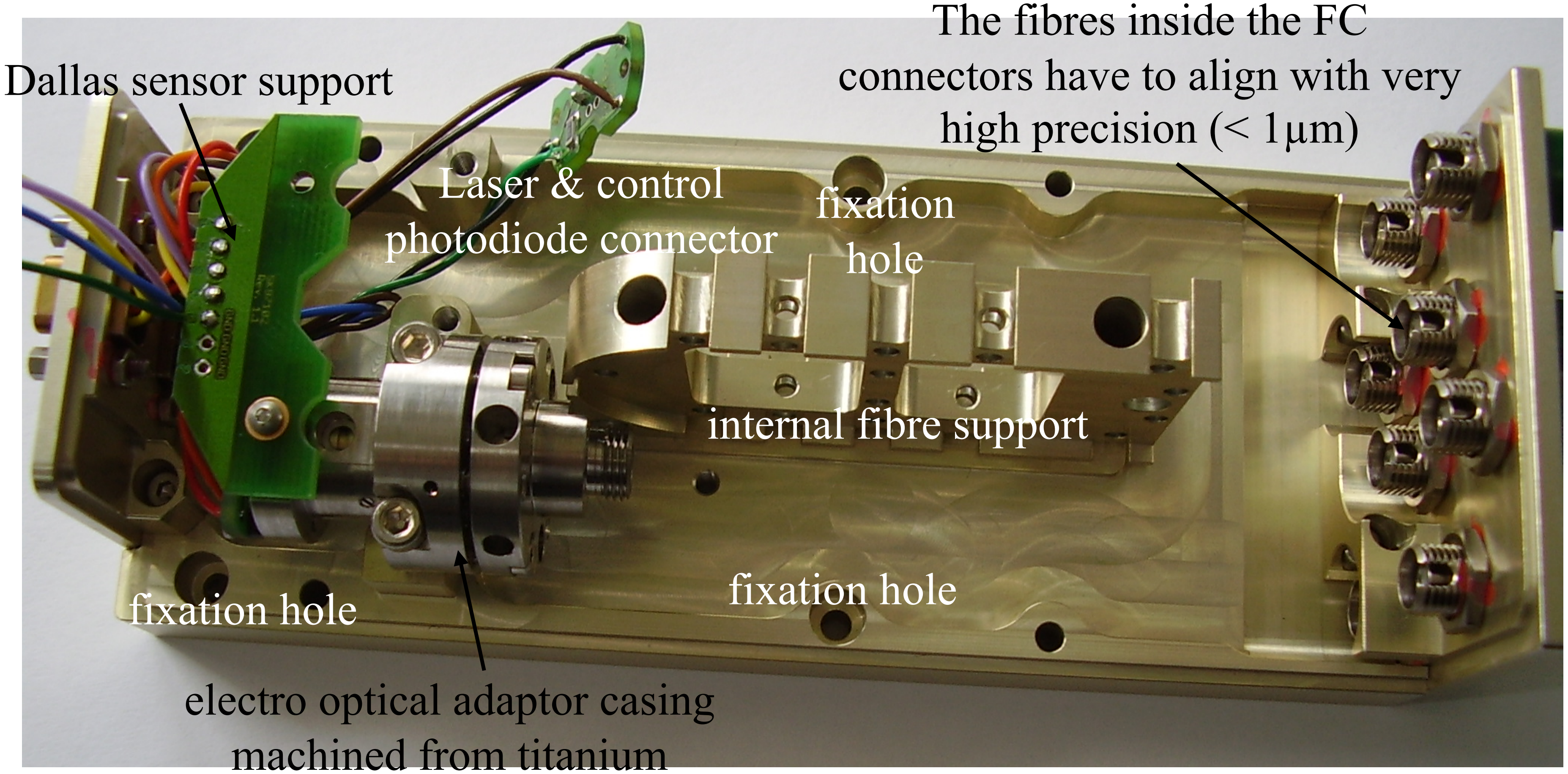
Laser Fiber Coupler (LFCR)



At low (< - 30°C) temperature the laser power is only 40 % from what is available above 10° C

The optical power reserve based on the diode performance and the pulsing system can cope with this variation

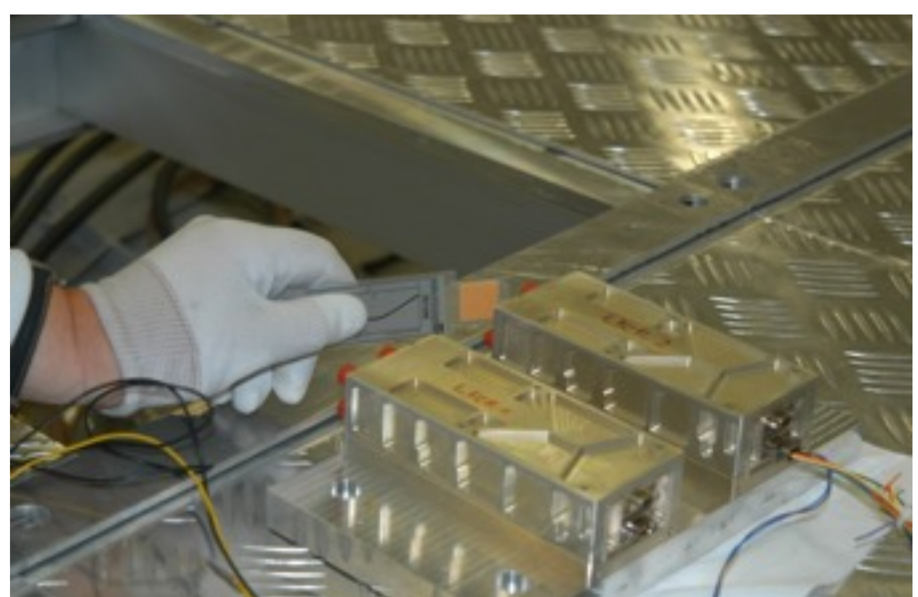
Laser Fiber Coupler (LFCR)



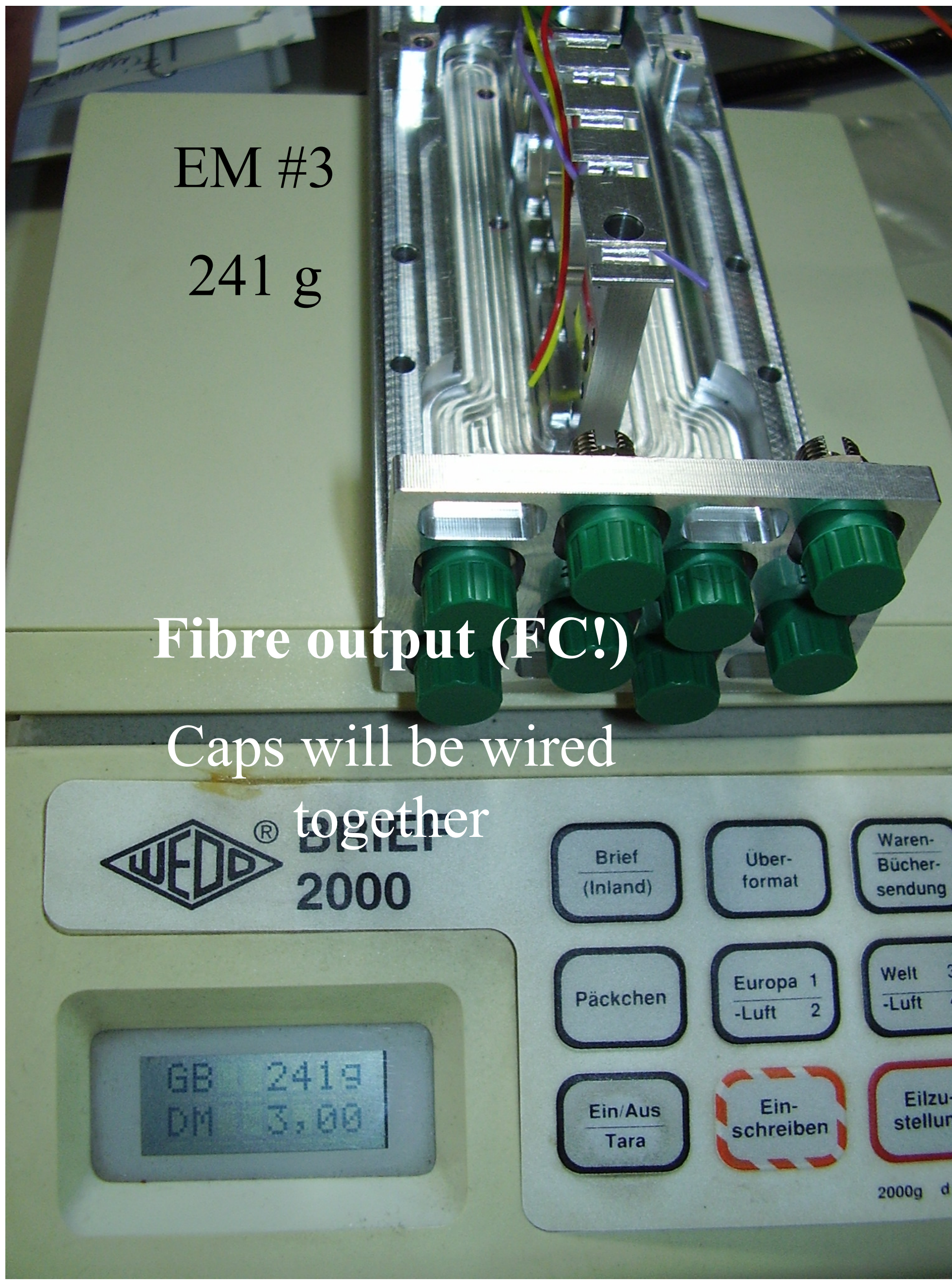
total LFCR weight : 350g

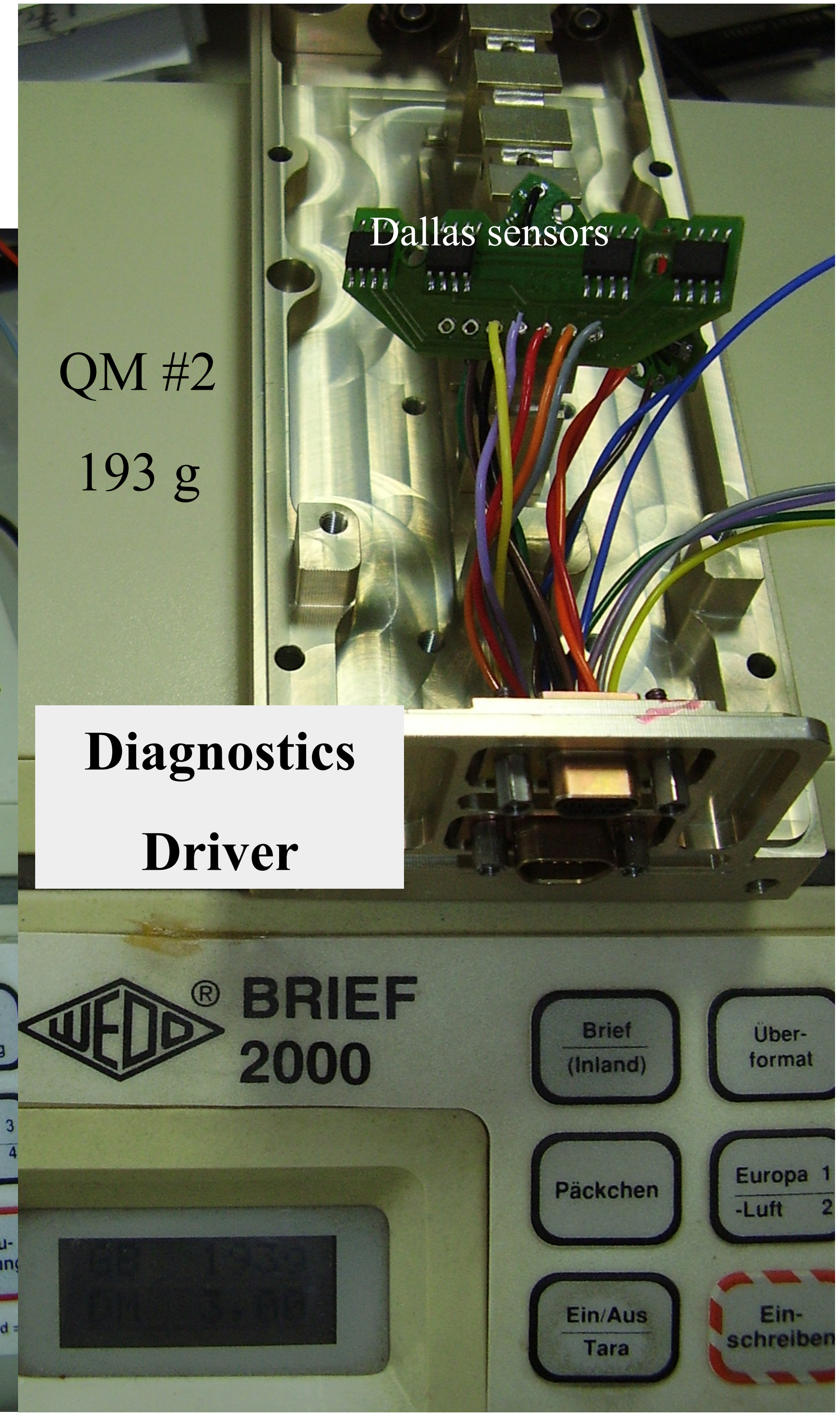
EM to QM: 30% weight reduction by improvement of mech. design

LFCR frame (QM) with 1 coupler and no splitters

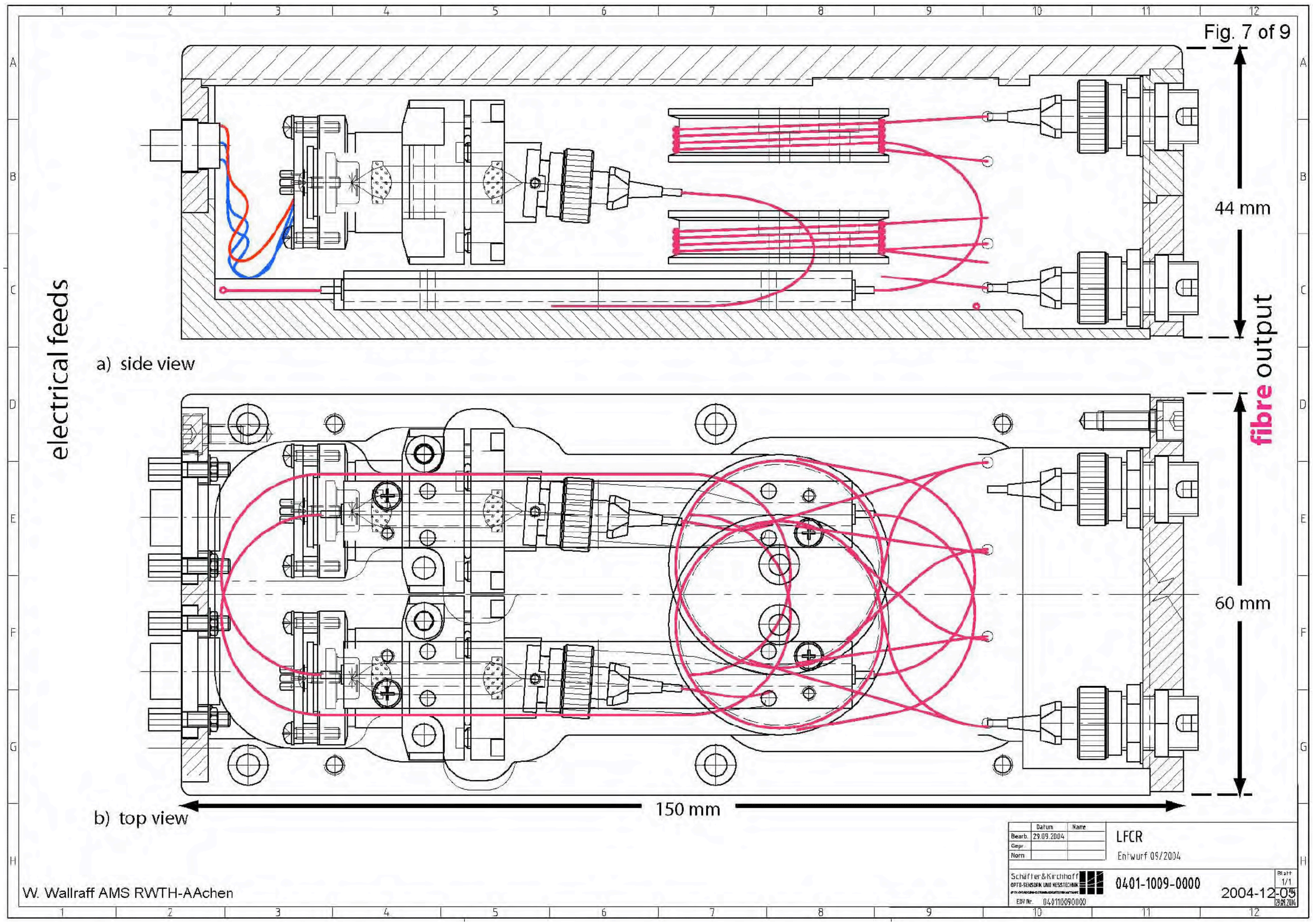


Laser Fiber Coupler (LFCR)

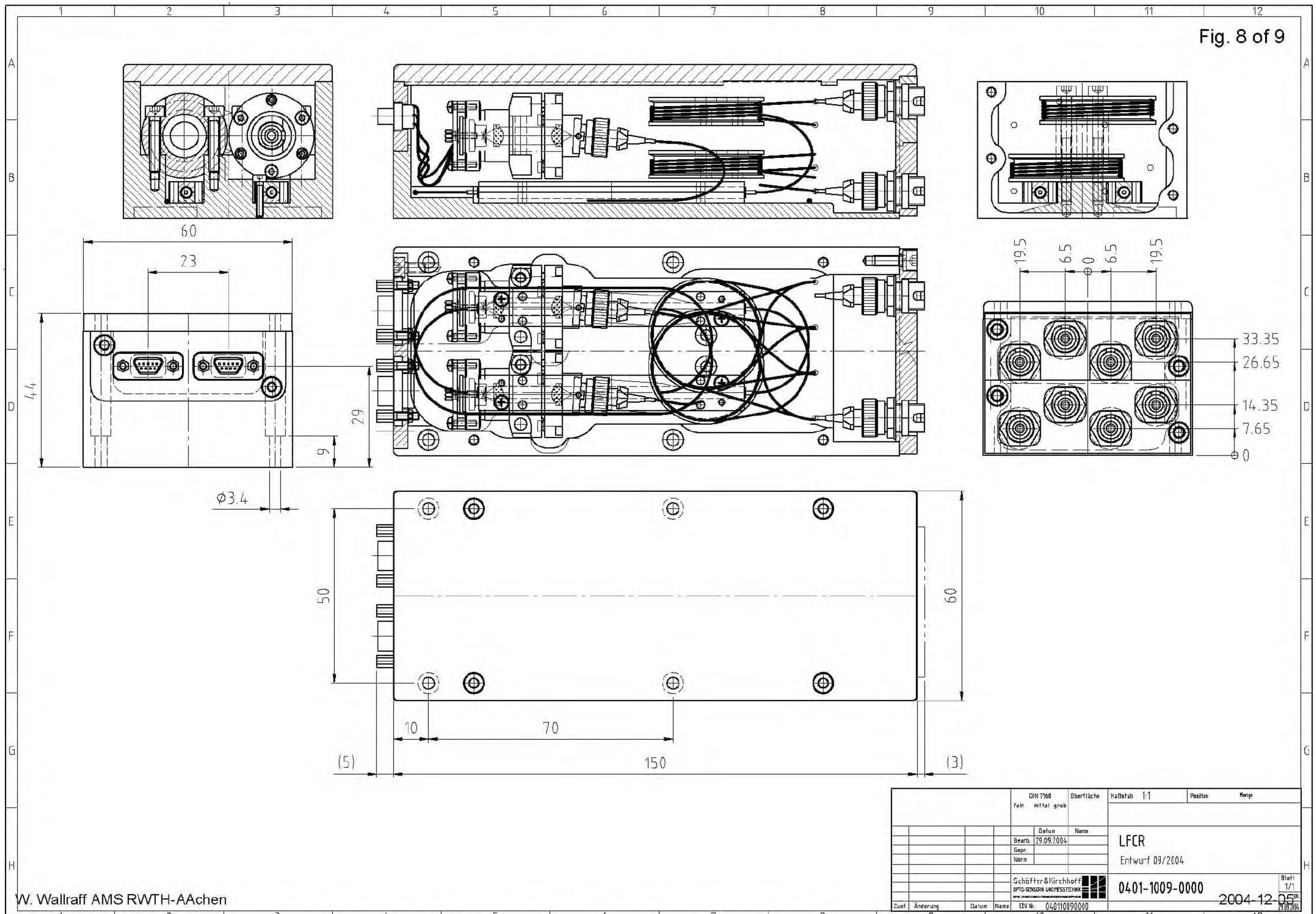




Laser Fiber Coupler (LFCR)



Laser Fiber Coupler (LFCR)



Laser Fiber Coupler (LFCR)

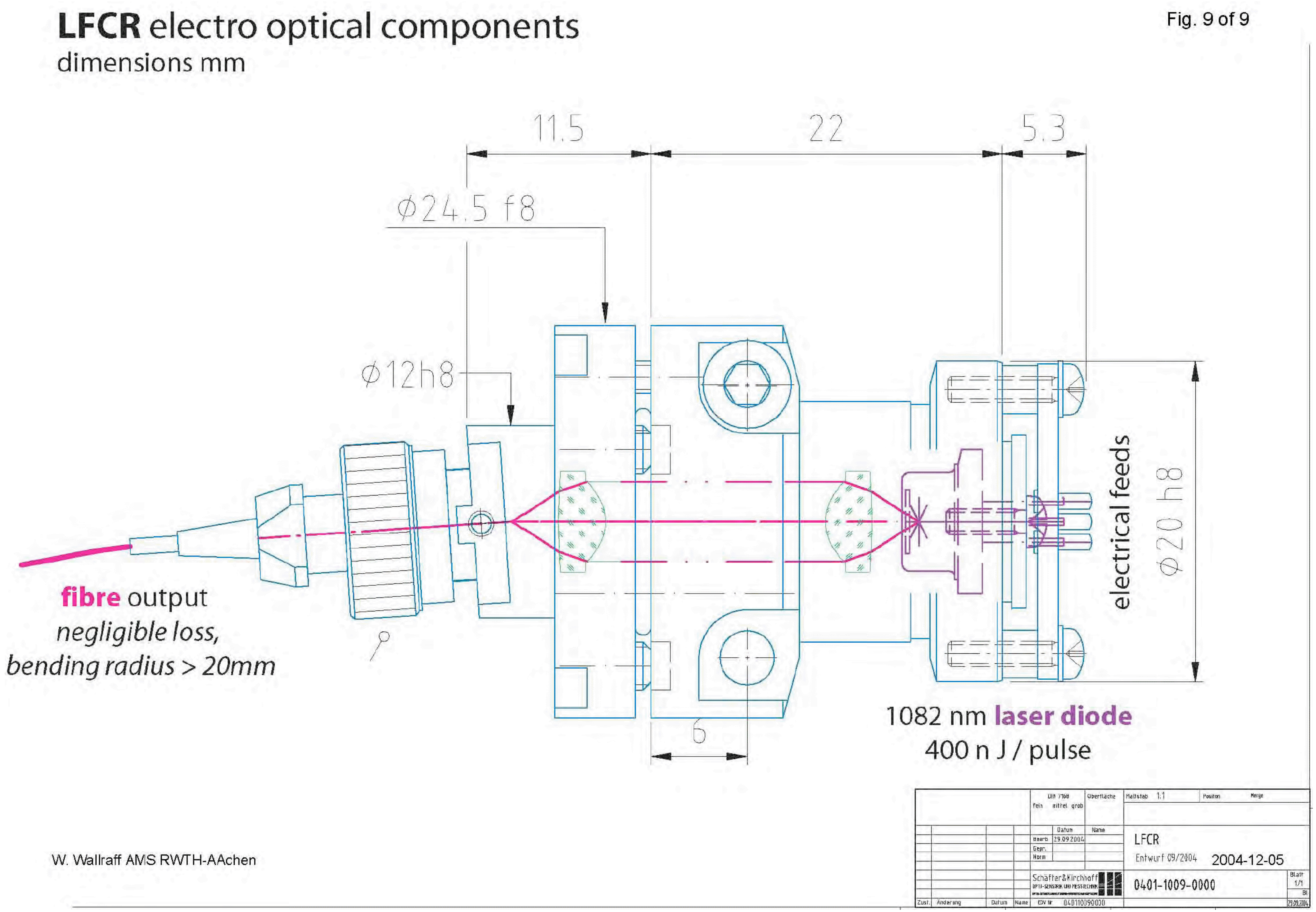
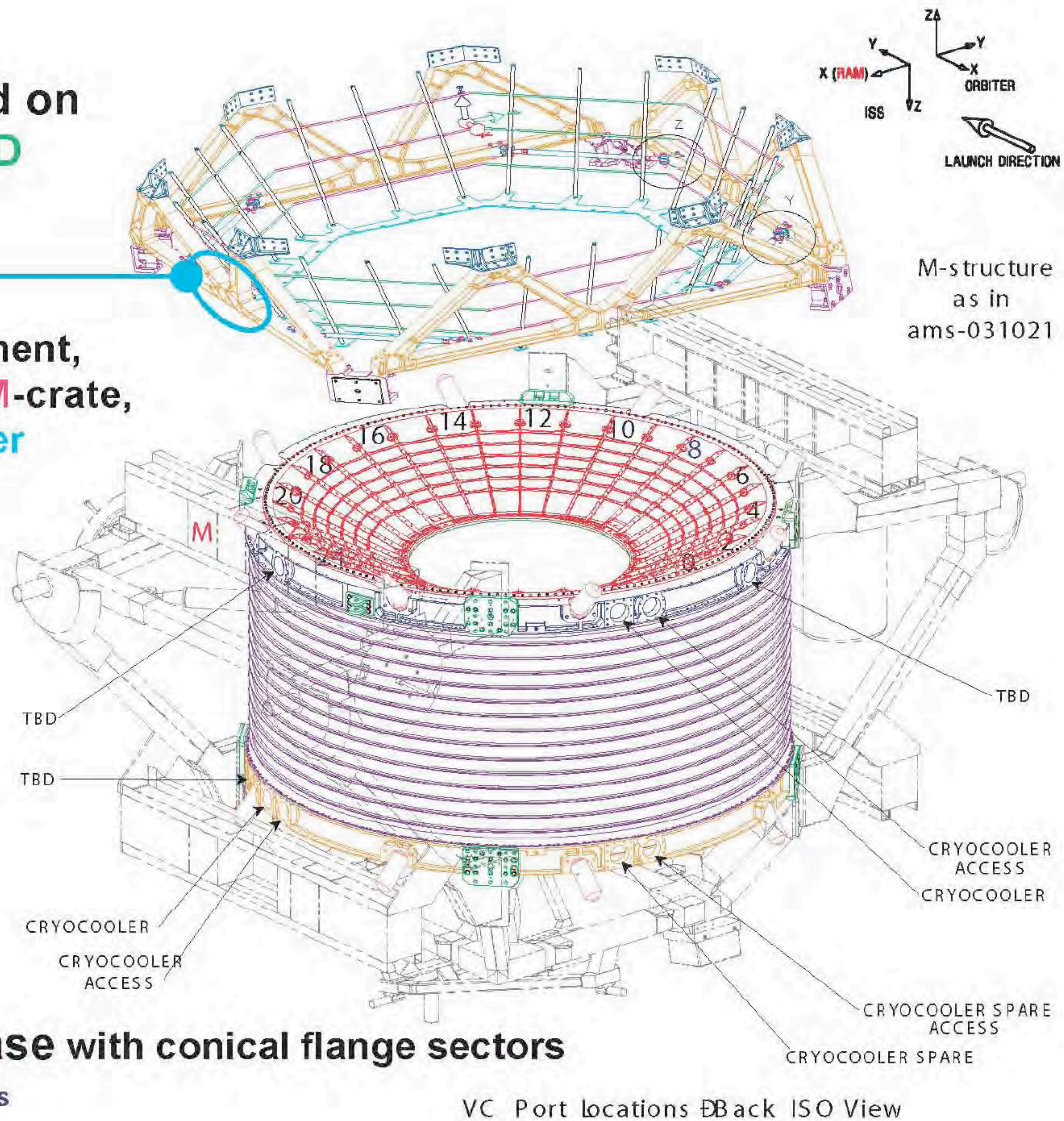


Fig. 5 of 9

TAS LFCR's will be mounted on the lower -y beam of the TRD M-structure (inside MLI):

well stabilized thermal environment, reasonably close to LDDR's in M-crate, not too difficult access to tracker plate 1(5)



Vacuum Case with conical flange sectors

used for ACC PMT's

W. Wallraff AMS RWTH-AAchen

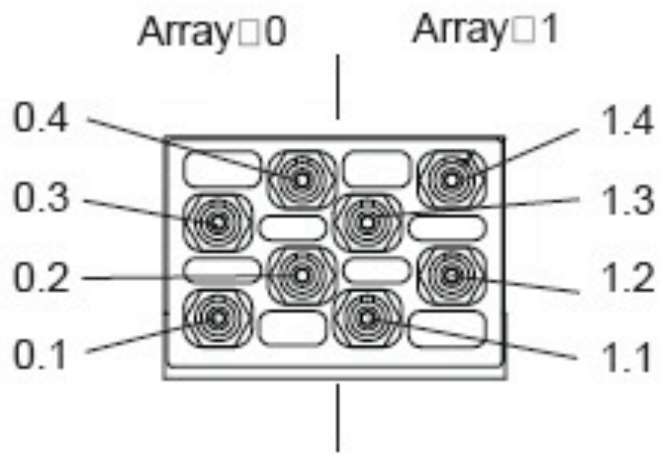
2004-12-05

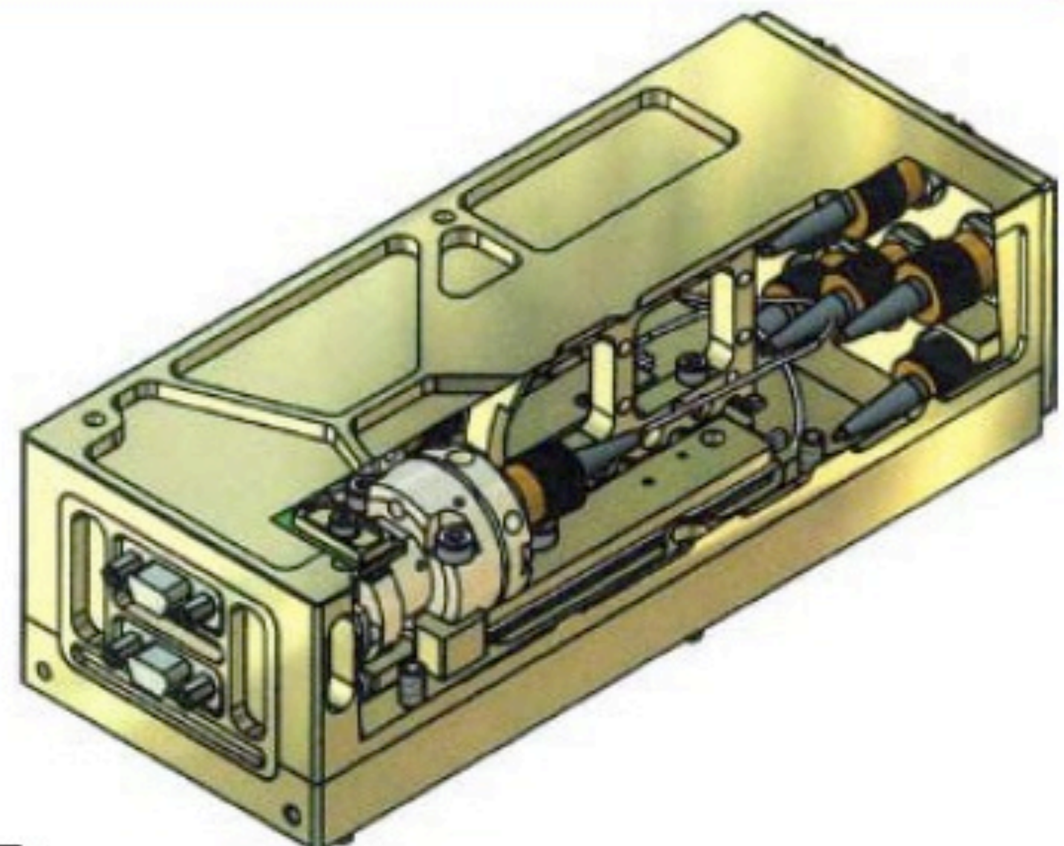
LFCRs Protokoll

LFCR Unit 1

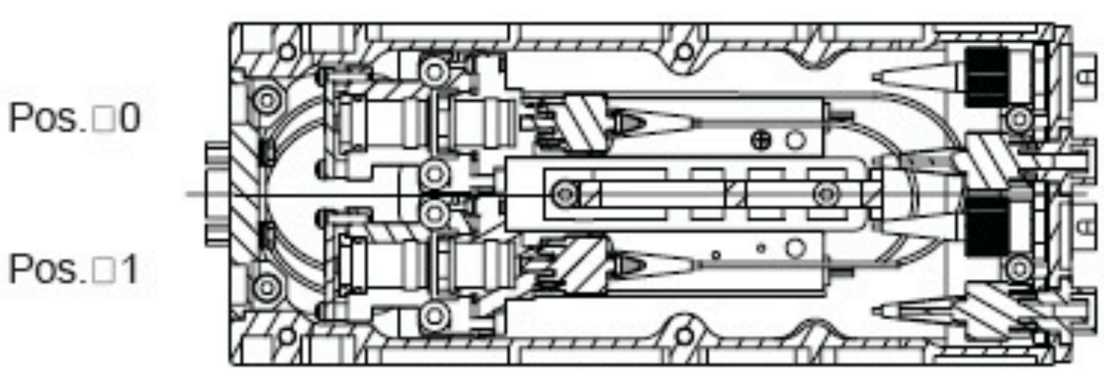
Laser Fiber Coupler for TAS at AMS-2, RWTH-Aachen

Nomenclature





The upper laser diode and splice coupler (Pos. 0) is related to the lower (left) connector array (Array 0) and vice versa.



Laser Diodes

Eagleyard					Measurement		
No.	I_{th} [mA]	I_{80mW} [mA]	slope [W/A]	$I_{80\%}$ [mA]	I_{PD} [mA]	$P_{collimated}$ [mW]	Port
714	23	113	0.86	95.00	16.00	54.40	1
715	19	110	0.86	91.80	14.00	51.50	2

For more information on the laser diodes see data sheet Eagleyard

Test LFCR

Unit	Position	Port	LD	Coupler	Fiber	P [mW]	Fiber No.	P [mW]	Kabel
Unit 1	Pos 1	Port 1	714	F306000	1.1	6.30	1100009	5.2	BL/BR
			20 μA		1.2	7.40	1100012	6.45	
			95 mA		1.3	5.20	1100006	4.5	
					1.4	6.30	1100009	5.13	
					Summe	**25.20**		**21.28**	
	Pos 0	Port 2	715	F305601	2.1	5.40	1100011	4.7	GN/SW
			18 μA		2.2	5.10	1100008	4.45	
			91.8 mA		2.3	5.40	1100010	4.7	
					2.4	6.00	1100005	5.6	
					Summe	**21.90**		**19.45**	

For more information on splice coupler data sheet FOC

Protokoll_LFCR.rtd

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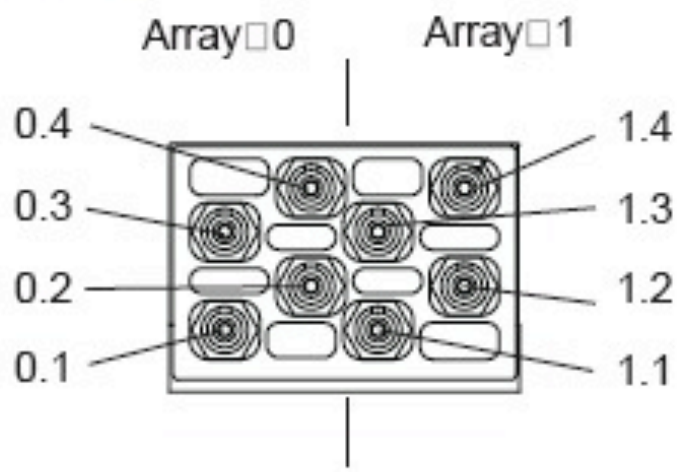
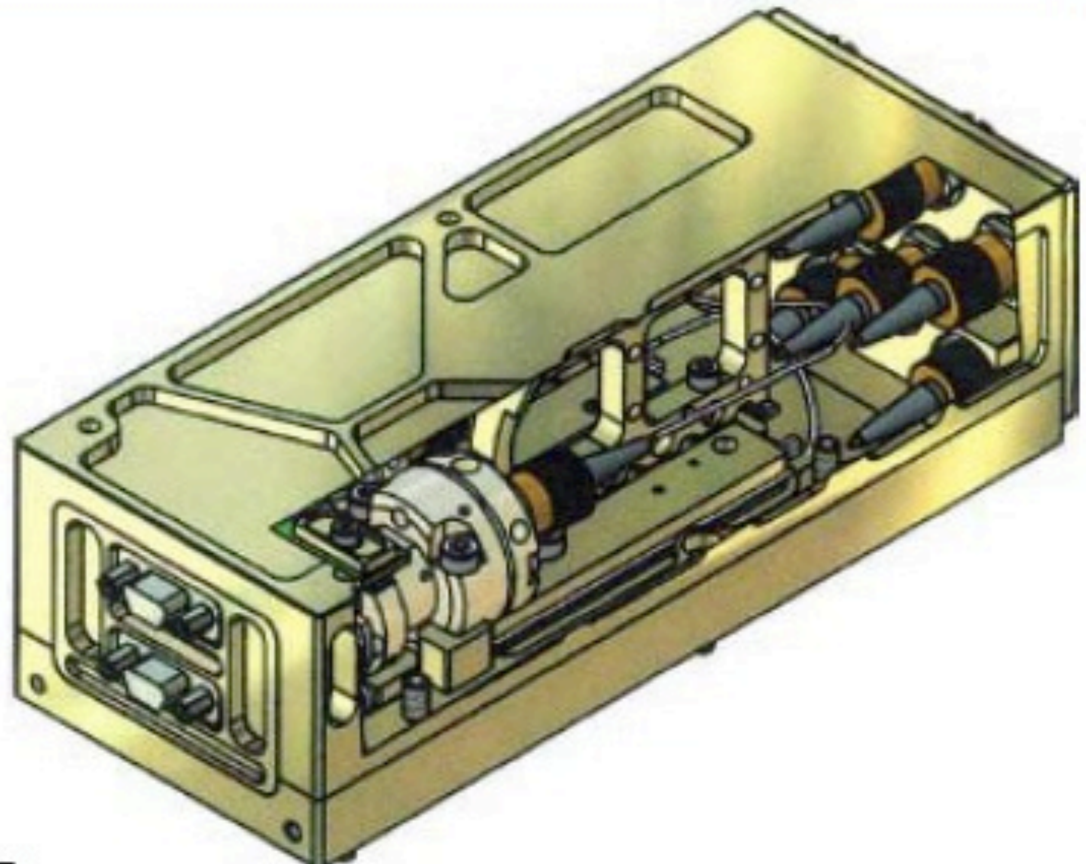
Celsiusweg 15, D-22761 Hamburg - Tel: +49 (0)40 853 997 0 - Fax: +49 (0)40 850 31 37 - eMail: info@SuKHamburg.de - Web: http://www.SuKHamburg.de

LFCR Unit 2

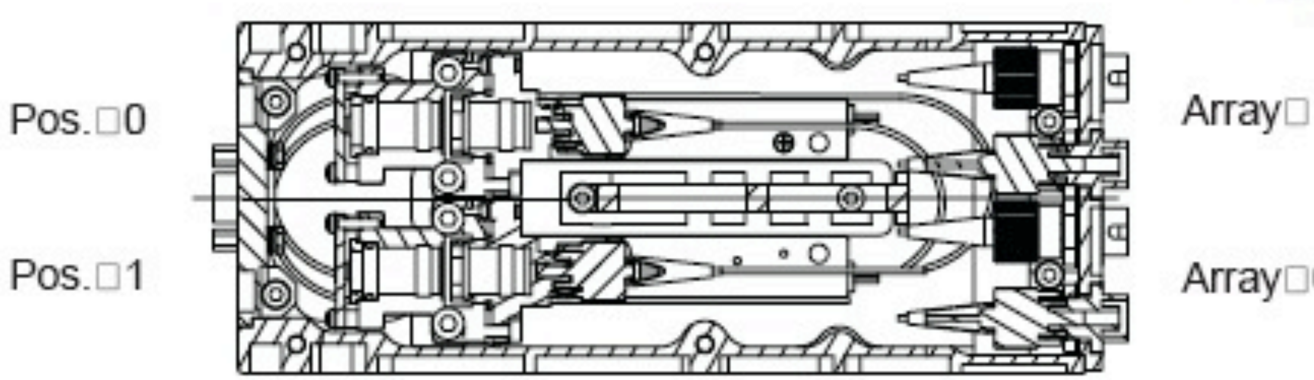
Laser Fiber Coupler for TAS at AMS-2, RWTH-Aachen

Nomenclature





The upper laser diode and splice coupler (Pos. 0) is related to the lower (left) connector array (Array 0) and vice versa.



Laser Diodes

Eagleyard					Measurement		
No.	I_{th} [mA]	I_{80mW} [mA]	slope [W/A]	$I_{80\%}$ [mA]	I_{PD} [mA]	$P_{collimated}$ [mW]	Port
716	18	103	0.92	86.00	16.00	53.10	3
717	19	103	0.92	86.20	14.00	52.00	4

For more information on the laser diodes see data sheet Eagleyard

Test LFCR

Unit	Position	Port	LD	Coupler	Fiber	P [mW]	Fiber No.	P [mW]	Kabel
Unit 2	Pos 1	Port 3	716	F305845	3.1	5.70			BL/BR
			20μA		3.2	5.10			
			86mA		3.3	6.20			
					3.4	6.10			
					Summe	**23.10**		**0**	
	Pos 0	Port 4	717	F306370	4.1	7.00			GN/SW
			17μA		4.2	6.00			
			86,2mA		4.3	6.20			
					4.4	4.60			
					Summe	**23.80**		**0**	

For more information on splice coupler data sheet FOC

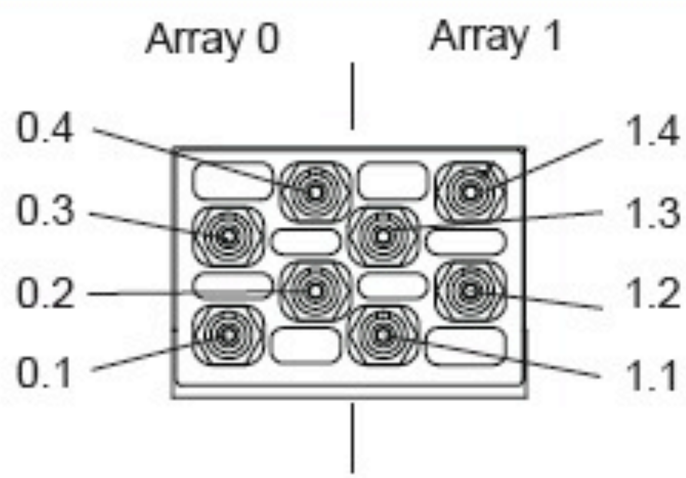
Protokoll_LFCR.rtd

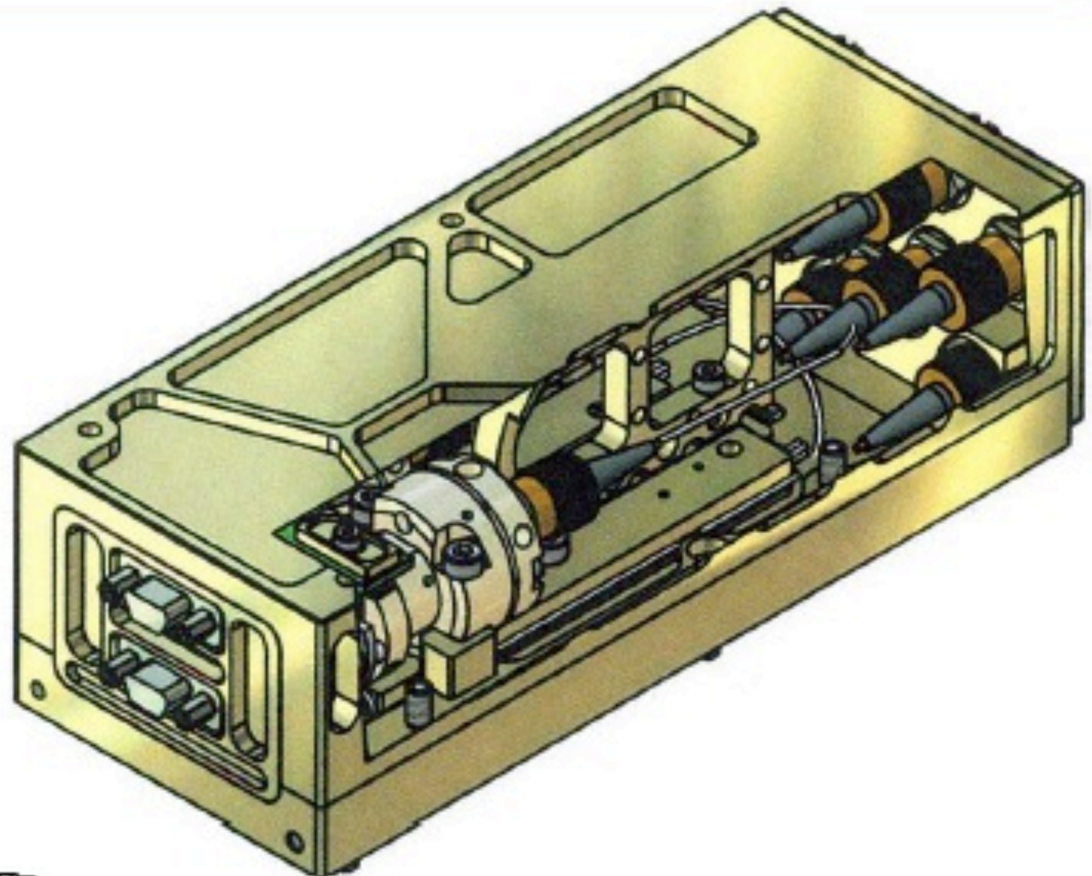
Schäfter + Kirchhoff GmbH
Celsiusweg 15, D-22761 Hamburg - Tel: +49 (0)40 853 997 0 - Fax: +49 (0)40 850 31 37 - eMail: info@SuKHamburg.de - Web: http://www.SuKHamburg.de

LFCR Unit 3

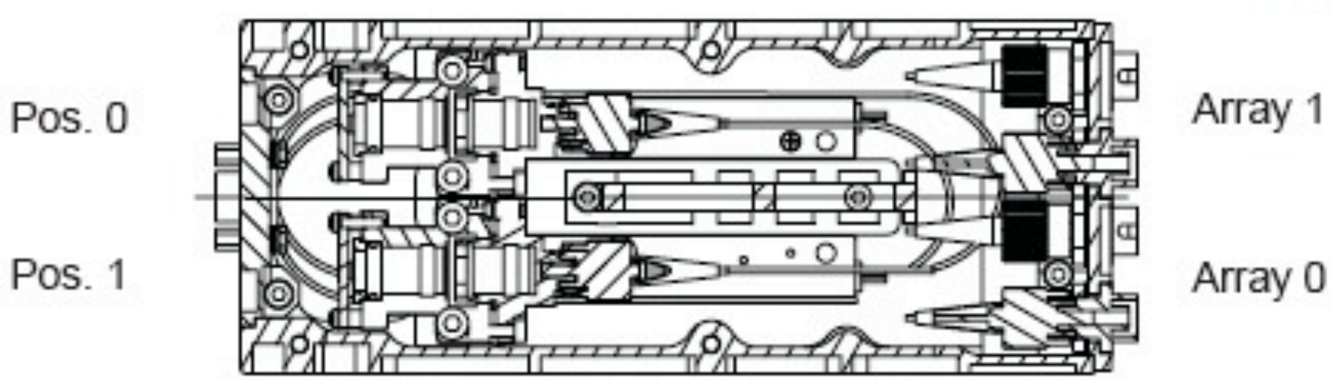
Laser Fiber Coupler for TAS at AMS-2, RWTH-Aachen

Nomenclature





The upper laser diode and splice coupler (Pos. 0) is related to the lower (left) connector array (Array 0) and vice versa.



Laser Diodes

Eagleyard					Measurement		
No.	I_{th} [mA]	I_{80mW} [mA]	slope [W/A]	$I_{80\%}$ [mA]	I_{PD} [mA]	$P_{collimated}$ [mW]	Port
703	19	104	0.91	87.00	16.00	50.30	5
704	19	104	0.92	87.00	16.00	51.60	6

For more information on the laser diodes see data sheet Eagleyard

Test LFCR

Unit	Position	Port	LD	Coupler	Fiber	P [mW]	Fiber No.	P [mW]	Kabel
Unit 3	Pos 1	Port 3	703	F013889	5.1	5.50			BL/BR
					5.2	4.90			
			87mA		5.3	4.50			
					5.4	6.40			
					Summe	**21.30**		**0**	
	Pos 0	Port 4	704	F013889	6.1	5.90			GN/SW
					6.2	5.30			
			87mA		6.3	5.90			
					6.4	5.80			
					Summe	**22.90**		**0**	

For more information on splice coupler data sheet FOC

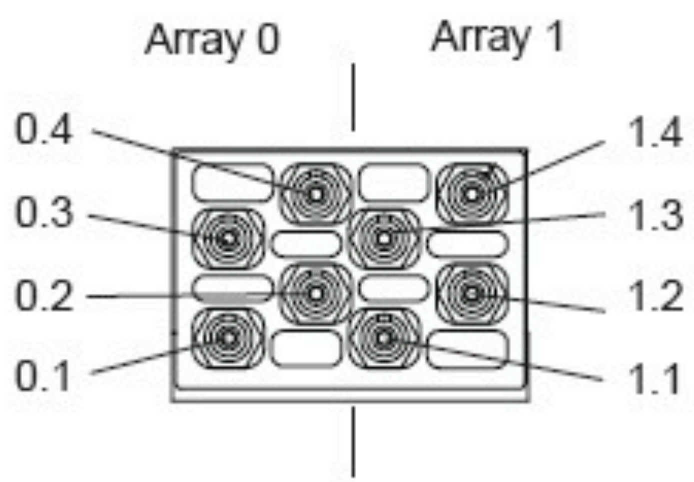
Protokoll_LFCR.rtd

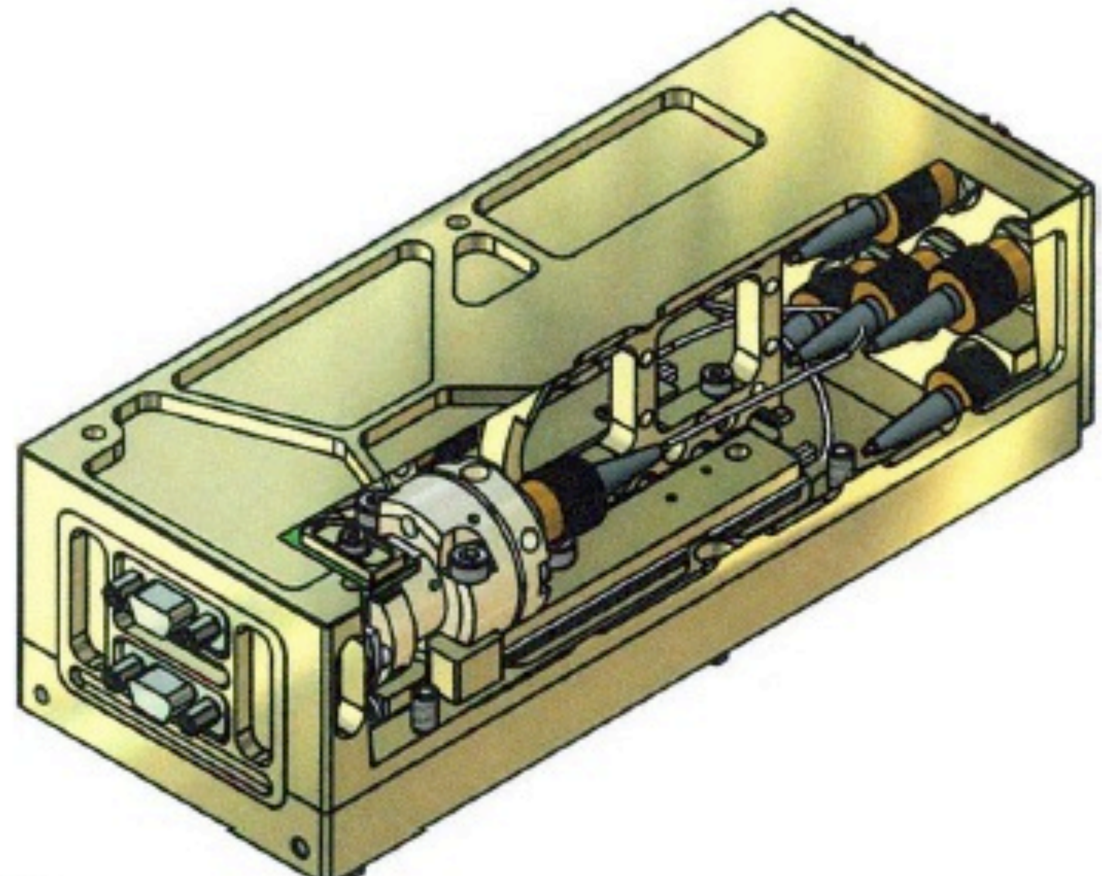
Schäfter + Kirchhoff

LFCR Unit 4

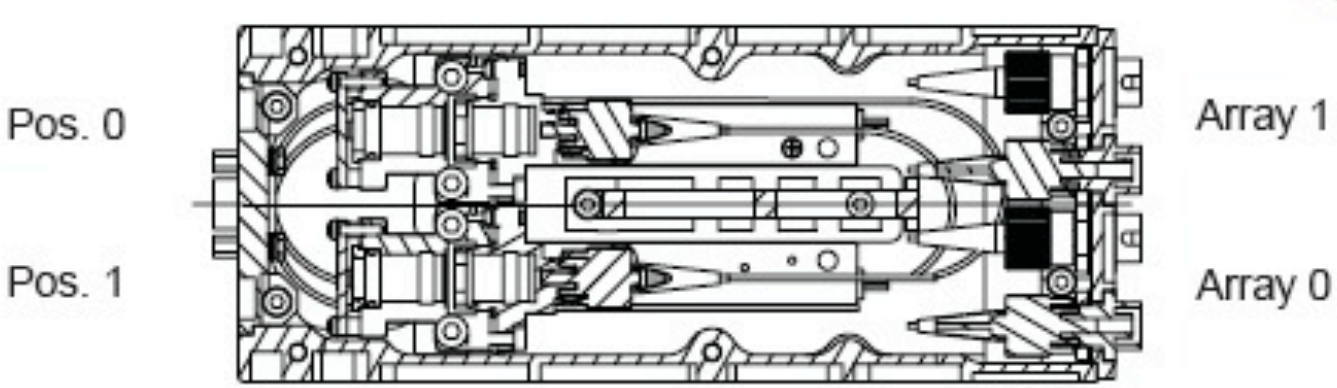
Laser Fiber Coupler for TAS at AMS-2, RWTH-Aachen

Nomenclature





The upper laser diode and splice coupler (Pos. 0) is related to the lower (left) connector array (Array 0) and vice versa.



Laser Diodes

Eagleyard					Measurement		
No.	I_{th} [mA]	I_{80mW} [mA]	slope [W/A]	$I_{80\%}$ [mA]	I_{PD} [mA]	$P_{collimated}$ [mW]	Port
705	22	109	0.89	91.60	16.00	50.20	7
706	20	111	0.86	92.80	15.00	51.50	8

For more information on the laser diodes see data sheet Eagleyard

Test LFCR

Unit	Position	Port	LD	Coupler	Fiber	P [mW]	Fiber No.	P [mW]	Kabel
Unit 4	**Pos 1**	Port 7	705	F0133883	7.1	5.80			BL/BR
					7.2	5.70			
			91,6mA		7.3	5.70			
					7.4	6.30			
					Summe	**23.50**		**0**	
	Pos 0	Port 8	706	F013891	8.1	7.10			GN/SW
					8.2	5.70			
			92,8mA		8.3	5.80			
					8.4	7.20			
					Summe	**25.80**		**0**	

For more information on splice coupler data sheet FOC

Protokoll_LFCR.rtf

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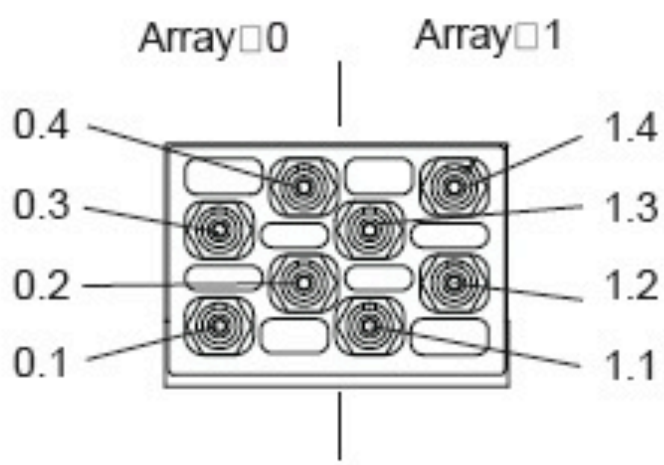
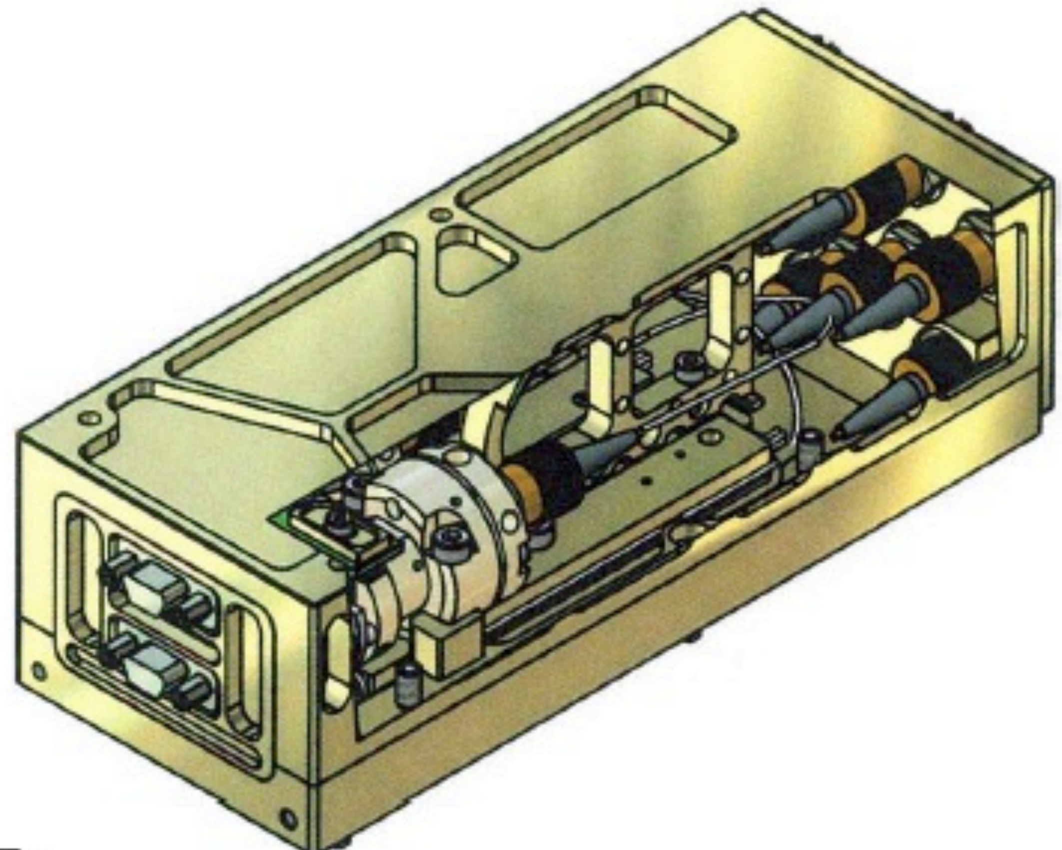
Kieler Str. 212, D-22525 Hamburg - Tel: +49 (0)40 853 997 0 - Fax: +49 (0)40 853 997 79 - eMail: info@SuKHamburg.de - Web: http://www.SuKHamburg.de

LFCR Unit 5

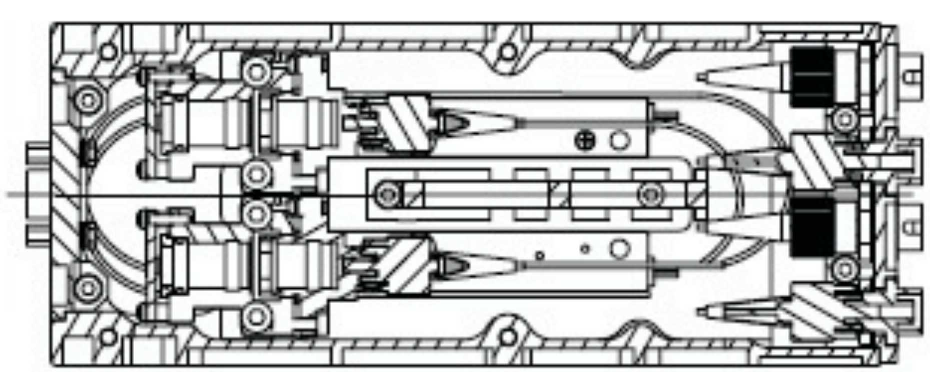
Laser Fiber Coupler for TAS at AMS-2, RWTH-Aachen

Nomenclature





The upper laser diode and splice coupler (Pos. 0) is related to the lower (left) connector array (Array 0) and vice versa.



Laser Diodes

Eagleyard					Measurement		
No.	I_{th} [mA]	I_{80mW} [mA]	slope [W/A]	$I_{80\%}$ [mA]	I_{PD} [mA]	$P_{collimated}$ [mW]	Port
709	22	111	0.86	93.20	14.00	50.10	9
710	21	107	0.89	89.80	15.00	50.10	10

For more information on the laser diodes see data sheet Eagleyard

Test LFCR

Unit	Position	Port	LD	Coupler	Fiber	P [mW]	Fiber No.	P [mW]	Kabel
Unit 5	Pos 1	Port 9	709	F013884	9.1	5.50			
					9.2	5.20			
			93.2mA		9.3	5.70			
					9.4	5.90			
					Summe	**22.30**		**0**	
	Pos 0	Port 10	710	F013885	10.1	6.50			GN/SW
					10.2	5.40			
			89.3mA		10.3	5.90			
					10.4	7.40			
					Summe	**25.20**		**0**	

For more information on splice coupler data sheet FOC

Protokoll_LFCR.rtd

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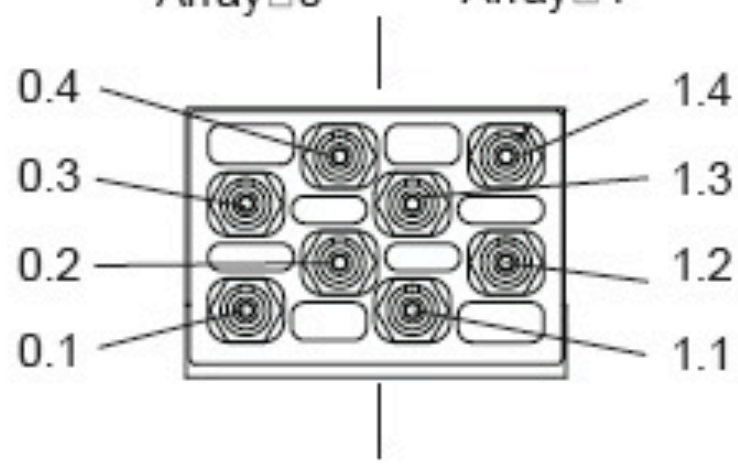
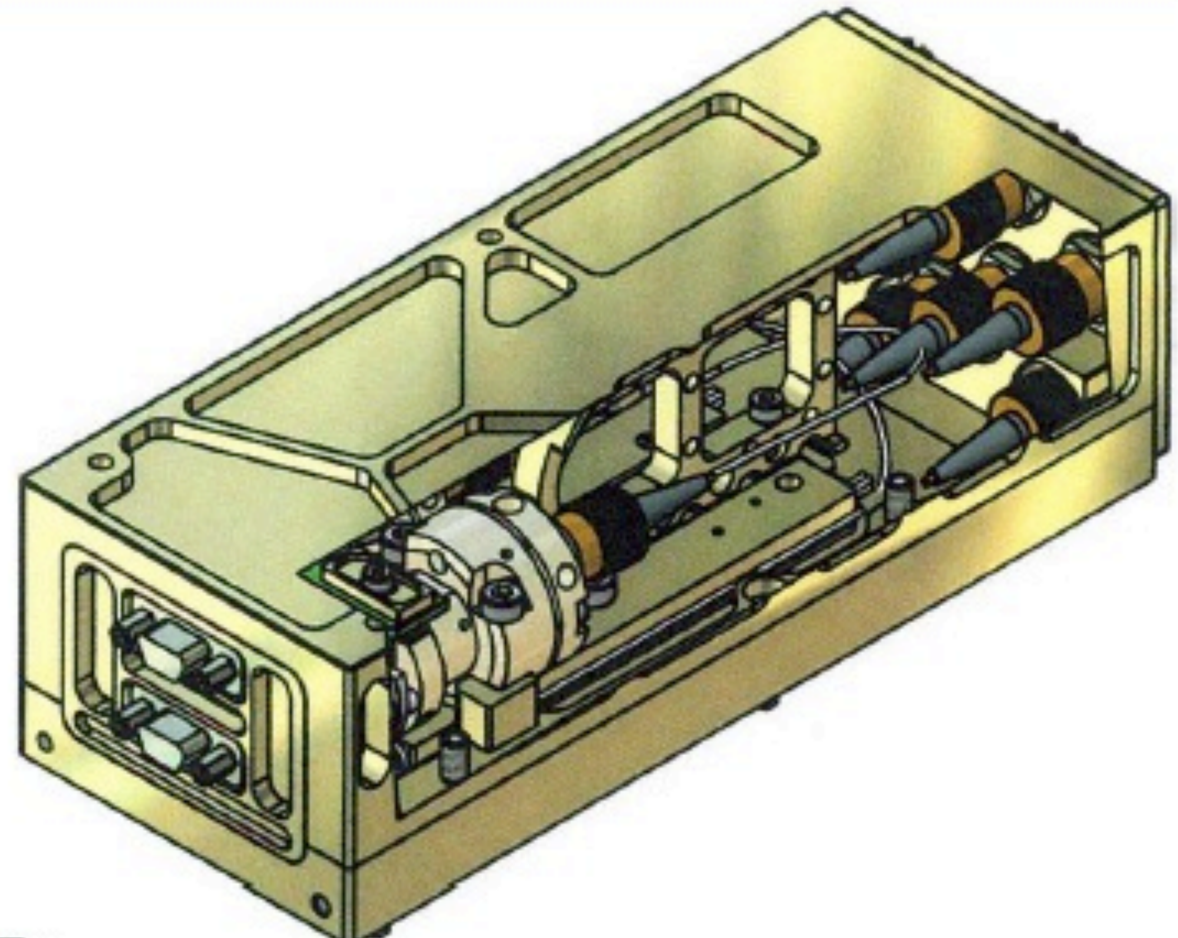
Kieler Str. 212, D-22525 Hamburg - Tel: +49 (0)40 853 997 0 - Fax: +49 (0)40 853 997 79 - eMail: info@SuKHamburg.de - Web: http://www.SuKHamburg.de

LFCR Unit 6

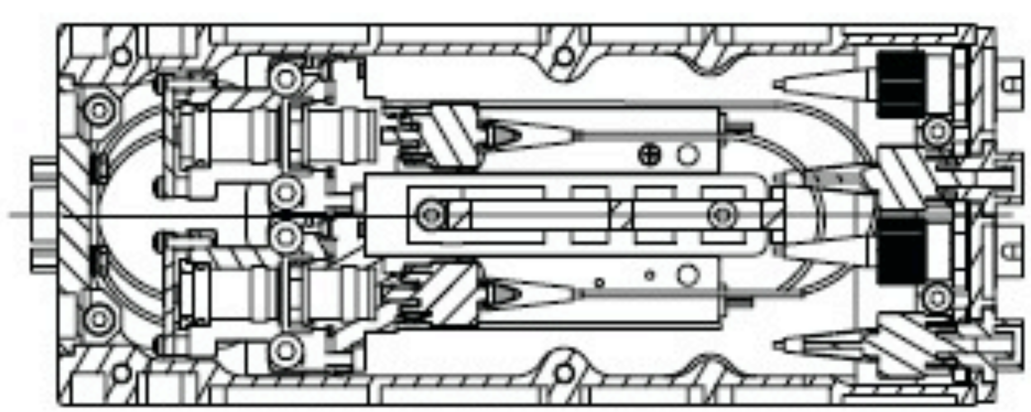
Laser Fiber Coupler for TAS at AMS-2, RWTH-Aachen

Nomenclature





The upper laser diode and splice coupler (Pos. 0) is related to the lower (left) connector array (Array 0) and vice versa.



Laser Diodes

Eagleyard					Measurement		
No.	I_{th} [mA]	I_{80mW} [mA]	slope [W/A]	$I_{80\%}$ [mA]	I_{PD} [mA]	$P_{collimated}$ [mW]	Port
711	20	105	0.91	88.00	15.00	48.00	11
712	21	107	0.9	89.80	15.00	48.30	12

For more information on the laser diodes see data sheet Eagleyard

Test LFCR

Unit	Position	Port	LD	Coupler	Fiber	P [mW]	Fiber No.	P [mW]	Kabel
Unit 6	Pos 1	Port 11	711	F0133886	11.1	6.20			
					11.2	5.70			
			88mA		11.3	6.05			
					11.4	6.70			
					Summe	**24.65**		**0**	
	Pos 0	Port 12	712	F013887	12.1	5.50			GN/SW
					12.2	6.40			
			89.8mA		12.3	5.60			
					12.4	4.90			
					Summe	**22.40**		**0**	

For more information on splice coupler data sheet FOC

Protokoll_LFCR.rtd

Schäfter + Kirchhoff GmbH
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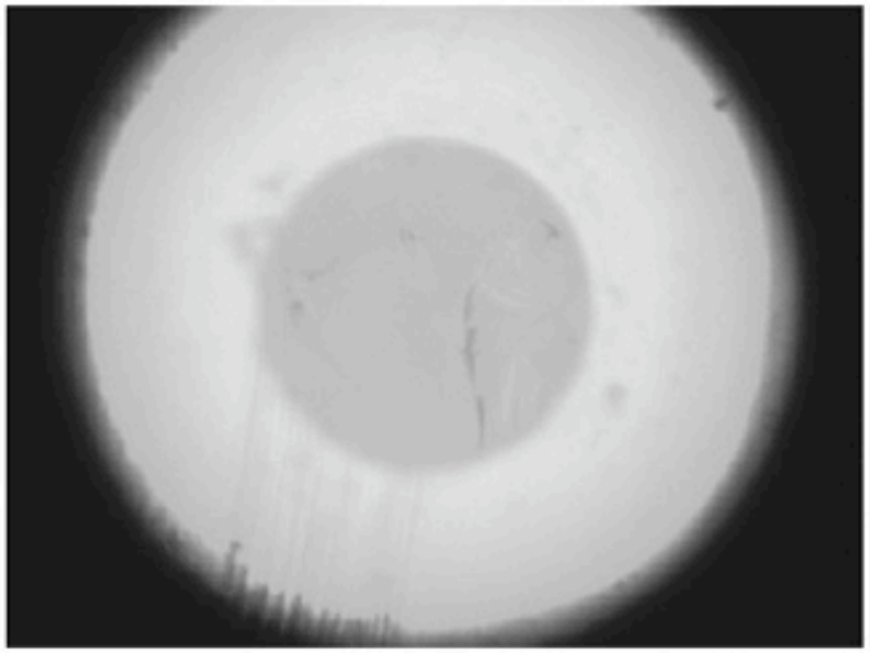
LFCRs FacettenBilder

Ad #46141 RWTH Aachen

LFCR Unit 3, Steckerfacetten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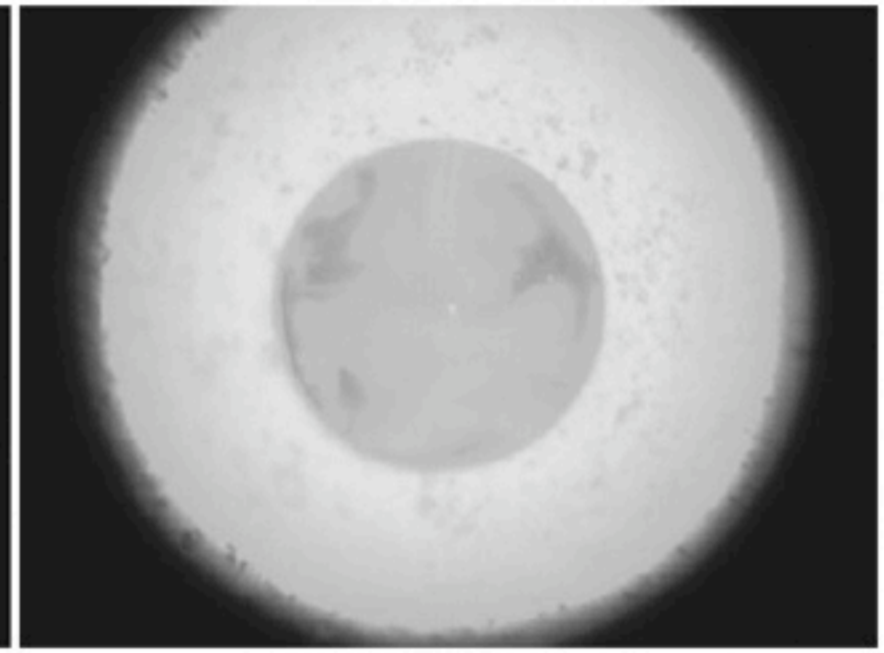
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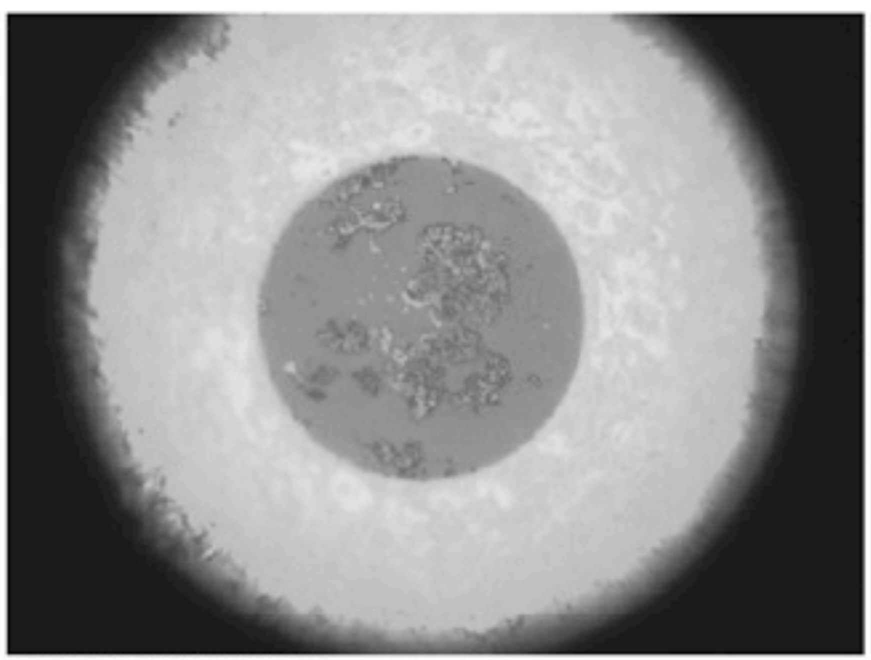
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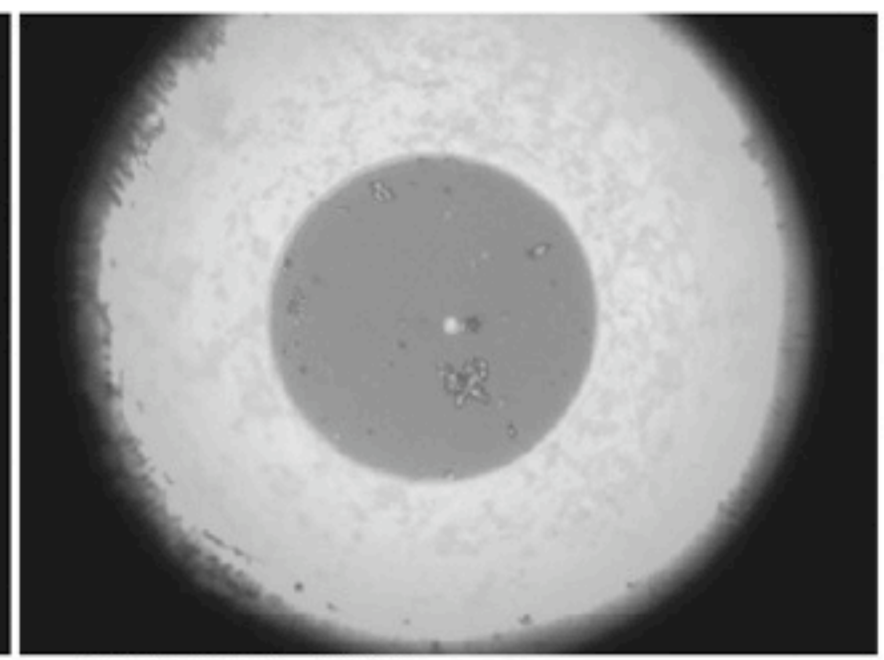
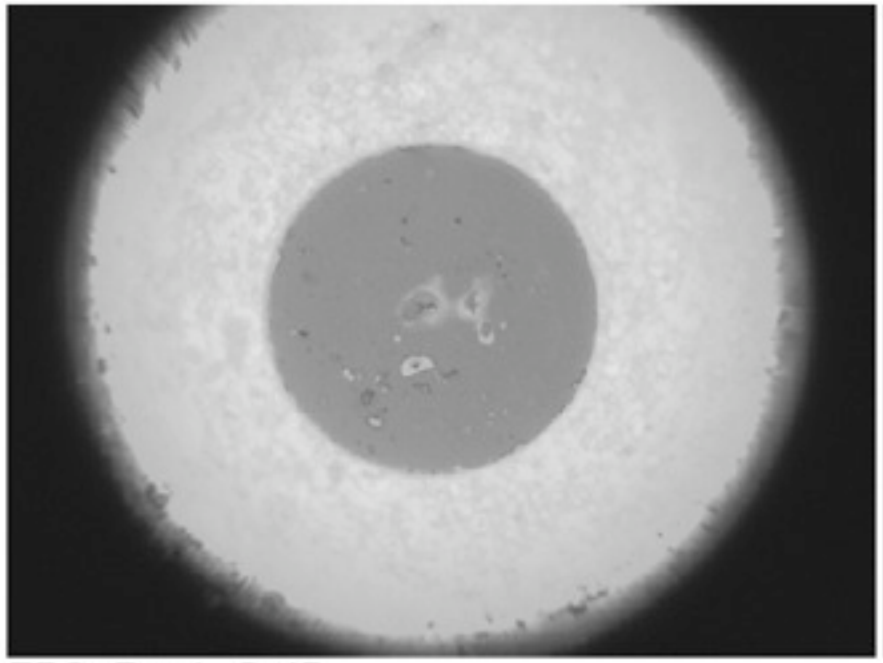
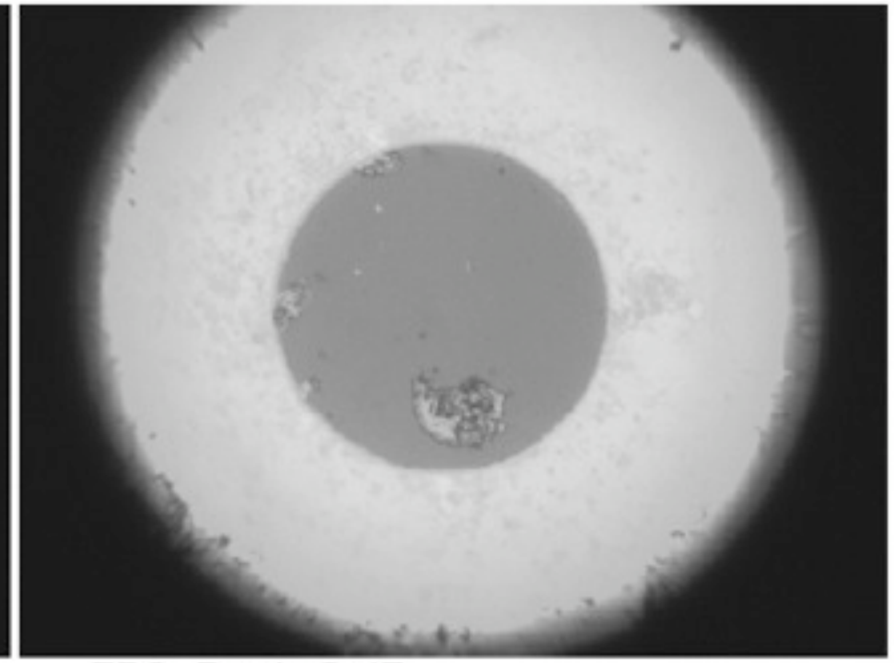
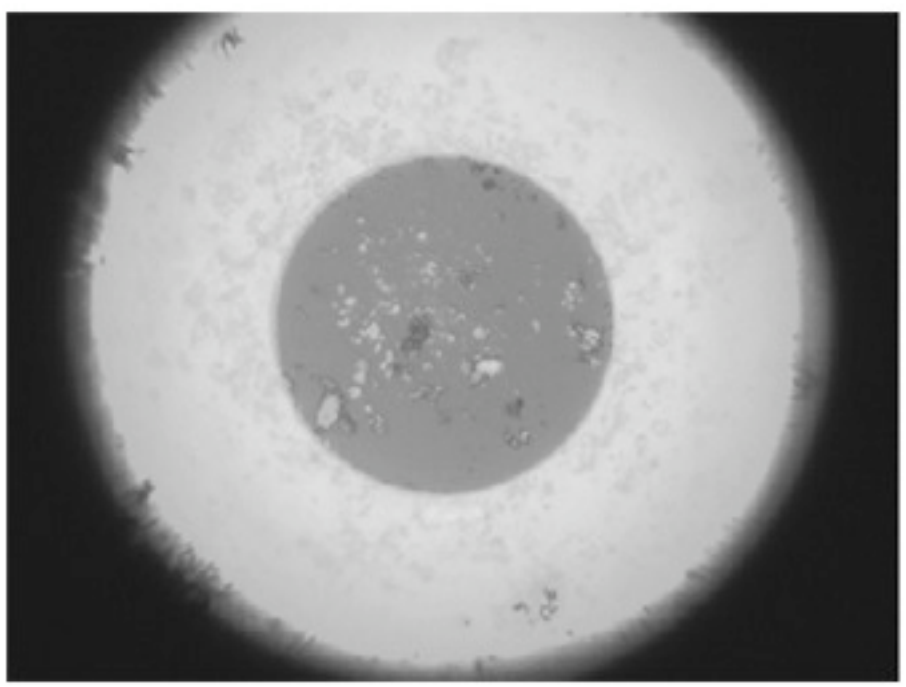

FBS_Pos0_Out8

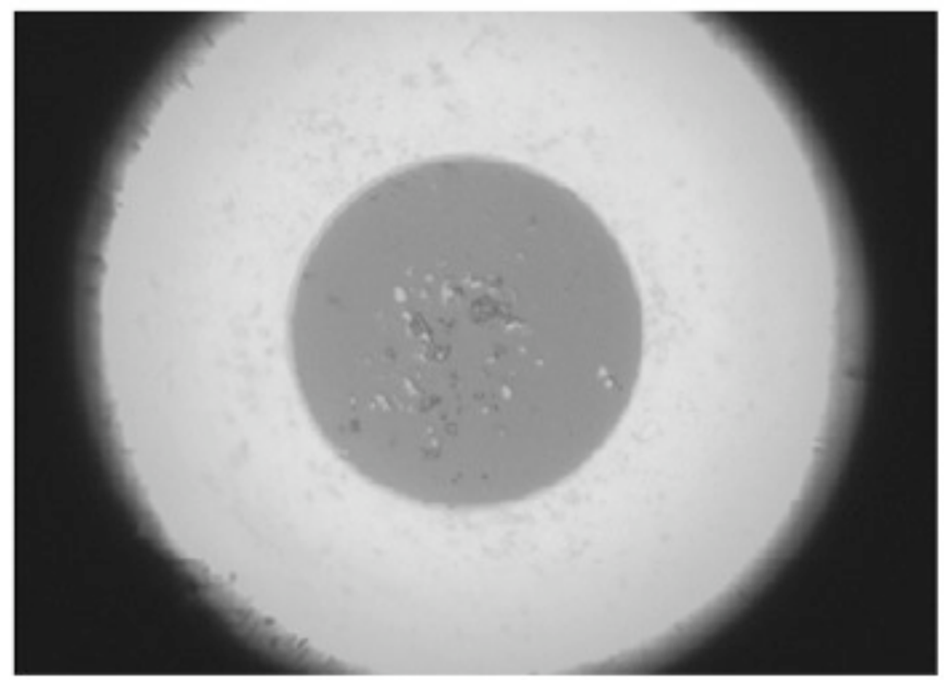


FBS_Pos1_Out5



FBS_Pos1_Out7





Eagleyard-LDs

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

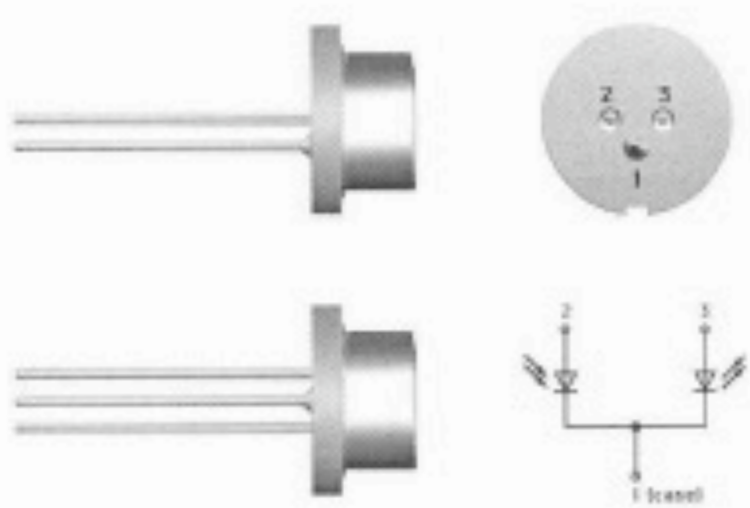
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051207**
Header	SOT	Header Number	**BA719**
λ at 80mW/nm	1078.37	Stripe Width/µm	3
Threshold Current/mA	19	Slope/ W/A	0.92
		Temperature/°C	25

Mode Structure fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:

Packed: 24 AUG. 2005

Signature: ....

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Page 1(2):

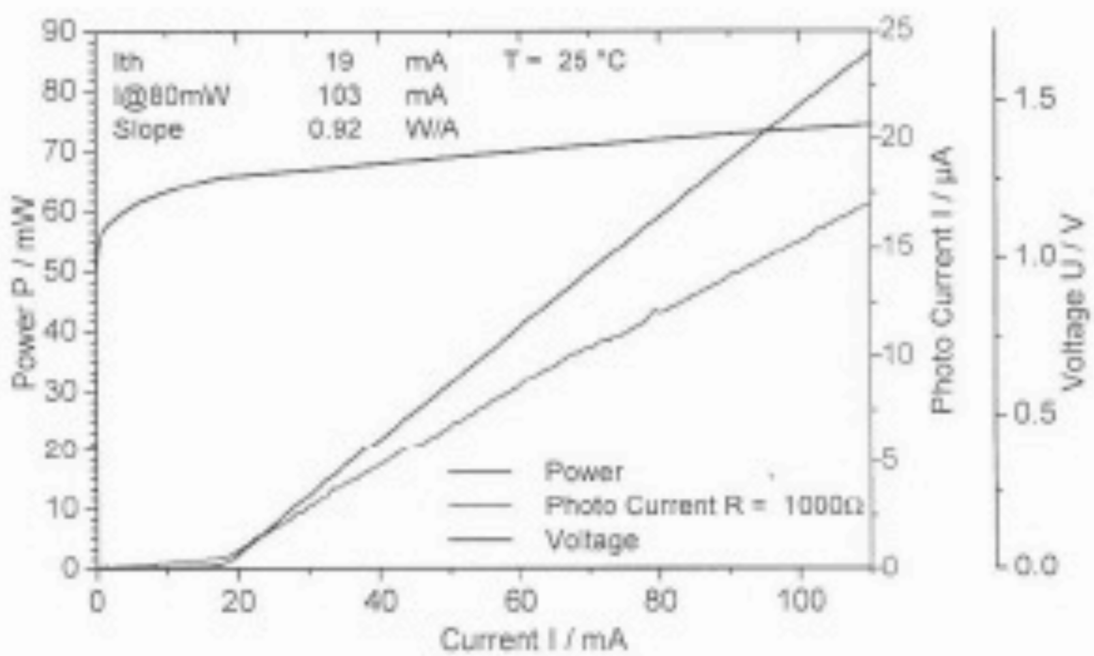
Measurement Results

Data of the Diode Laser:

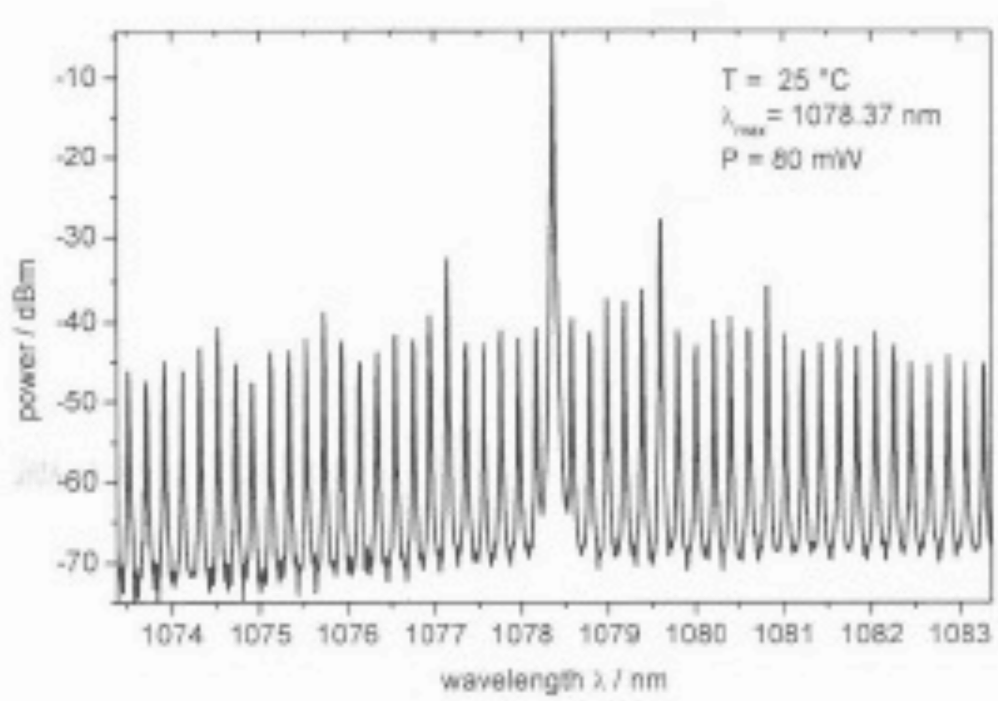
Charge	**022084** (0987/1105)	Diode	**051207**
Header	SOT	Header Number	**BA719**

Data:

P-I-characteristic:



Spectrum:



Page 2(2):

eagleyard PHOTONICS

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

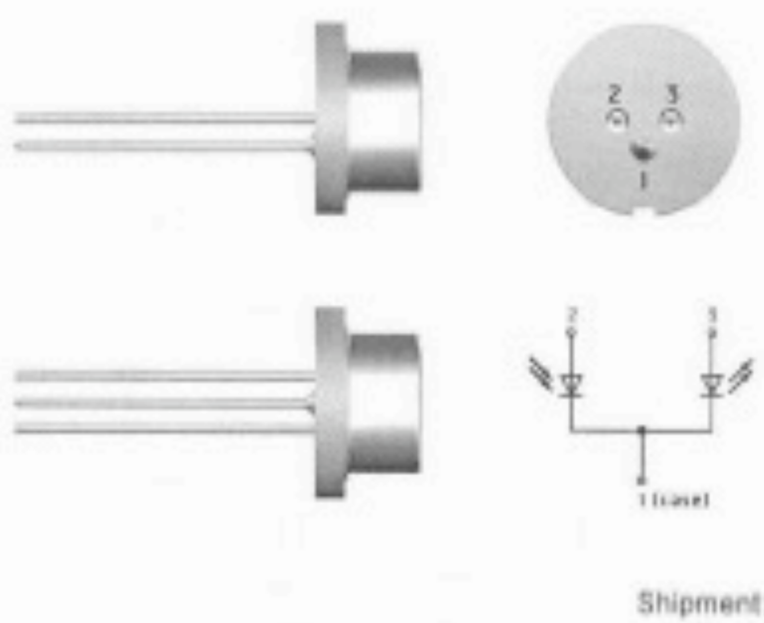
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051206**
Header	SOT	Header Number	**BA718**
λ at 80mW/nm	1077.39	Stripe Width/µm	3
Threshold Current/mA	22	Slope/ W/A	0.85
		Temperature/°C	25

Mode Structure fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:

Packed: 22 AUG. 2005

Signature: ......Widmer......

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Page 1(2)

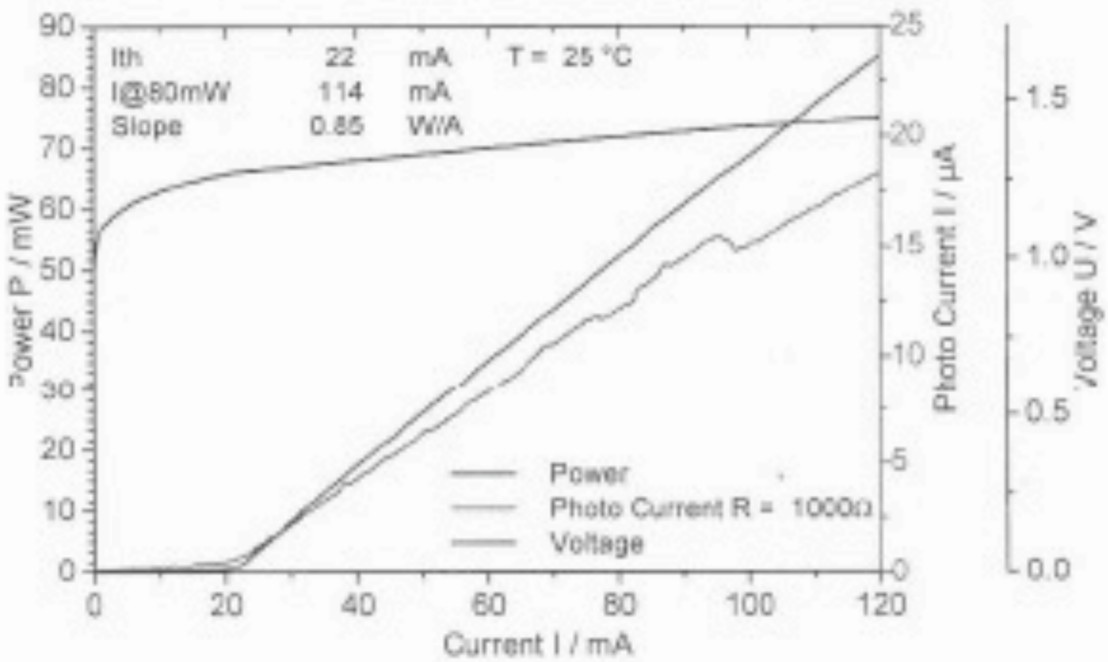
Measurement Results

Data of the Diode Laser:

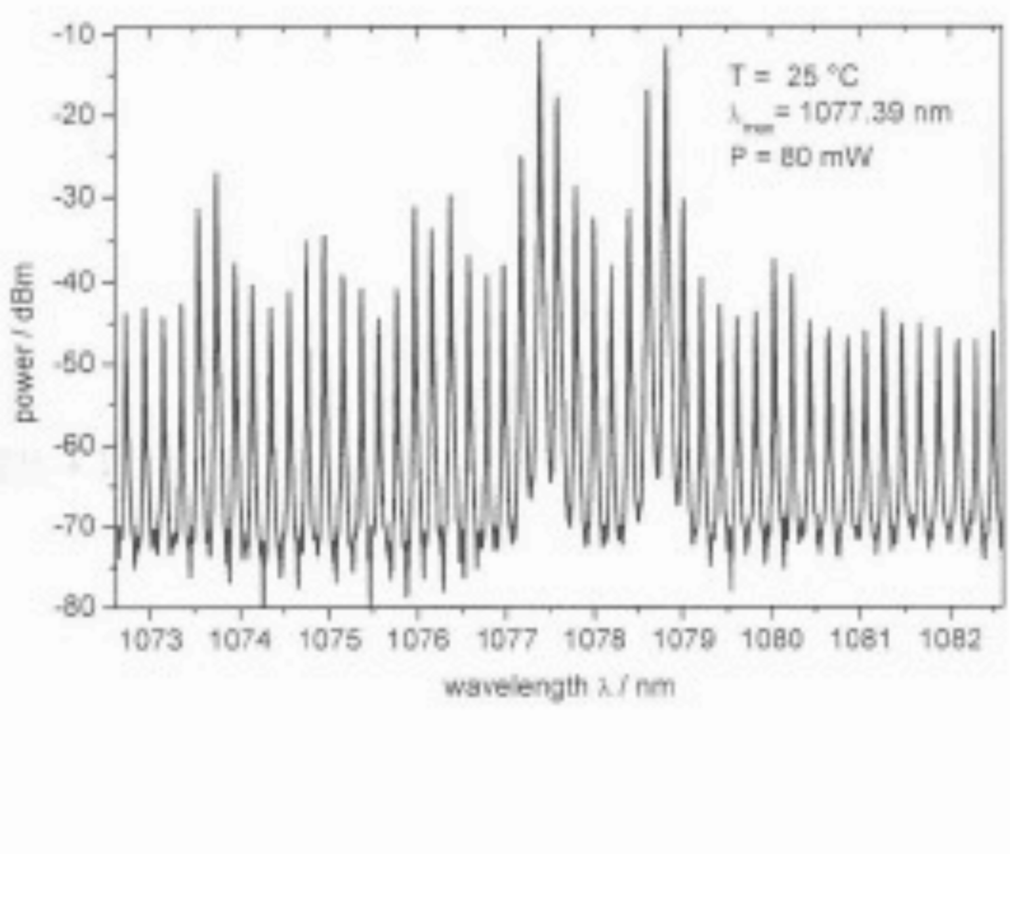
Charge	**022084** (0987/1105)	Diode	**051206**
Header	SOT	Header Number	**BA718**

Data:

P-I-characteristic:



Spectrum:



Page 2(2):

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

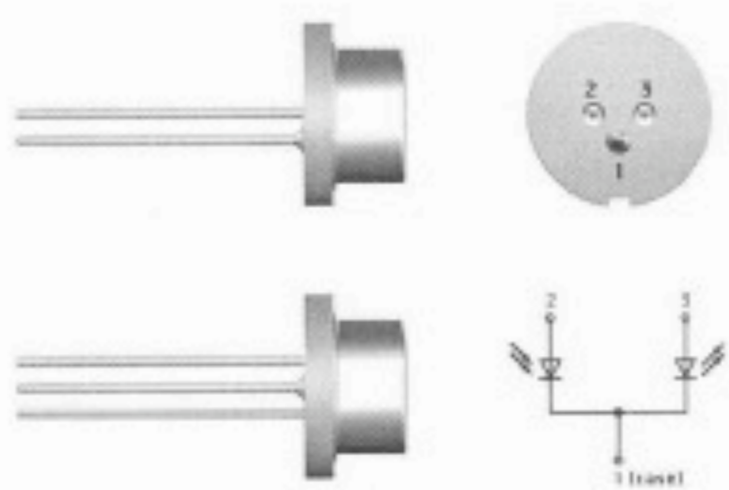
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051205**
Header	SOT	Header Number	**BA717**
λ at 80mW/nm	1077.79	Stripe Width/µm	3
Threshold Current/mA	19	Slope/ W/A	0.92
		Temperature/°C	25

Mode Structure fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:

Packed: 22. AUG. 2005

Signature: ...Widmann.....

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Page 1(2)

eagleyard PHOTONICS

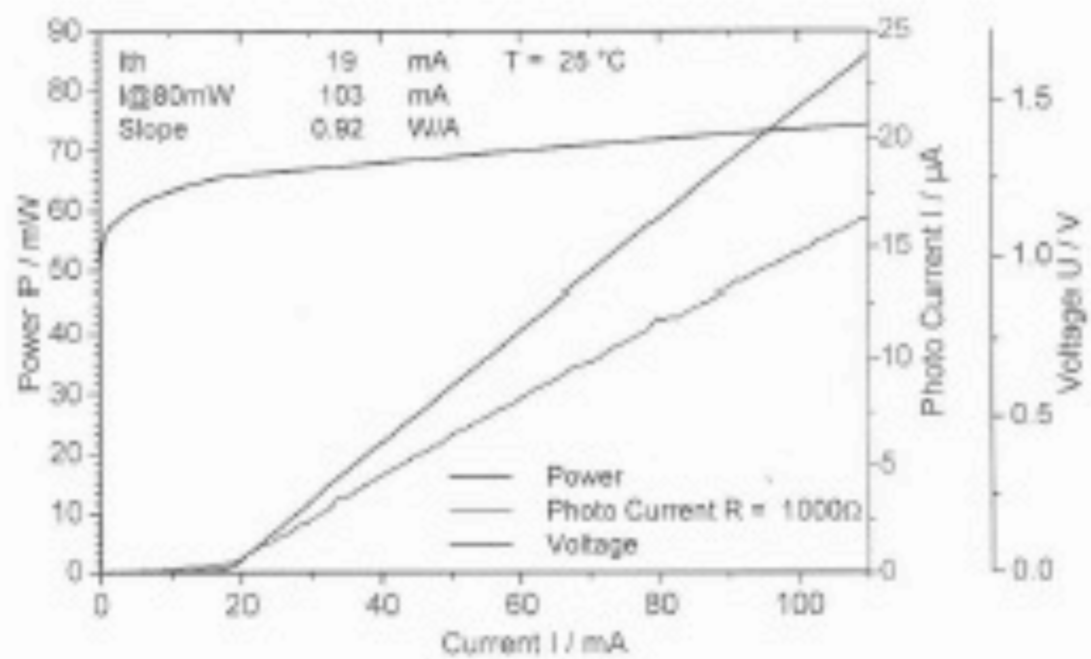
Measurement Results

Data of the Diode Laser:

Charge	022084 (0987/1105)	Diode	051205
Header	SOT	Header Number	BA717

Data:

P-I-characteristic:



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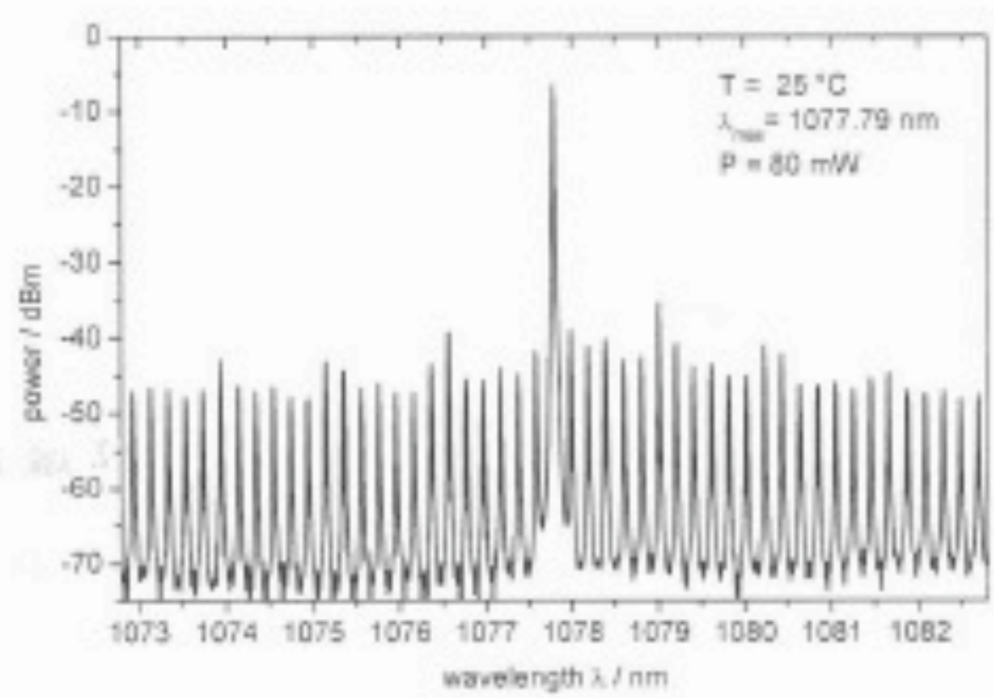


Page 2(2)

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

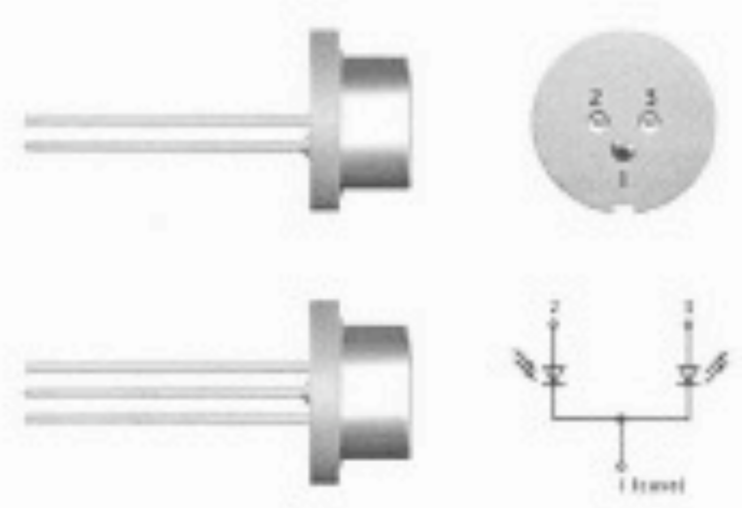
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051203**
Header	SOT	Header Number	**BA716**
λ at 80mW/nm	1077.76	Stripe Width/µm	3
Threshold Current/mA	18	Slope/ W/A	0.92
		Temperature/°C	25

Mode Structure fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:

Packed: 22 AUG. 2005

Signature: ....Widmann.....

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Page 1(2):

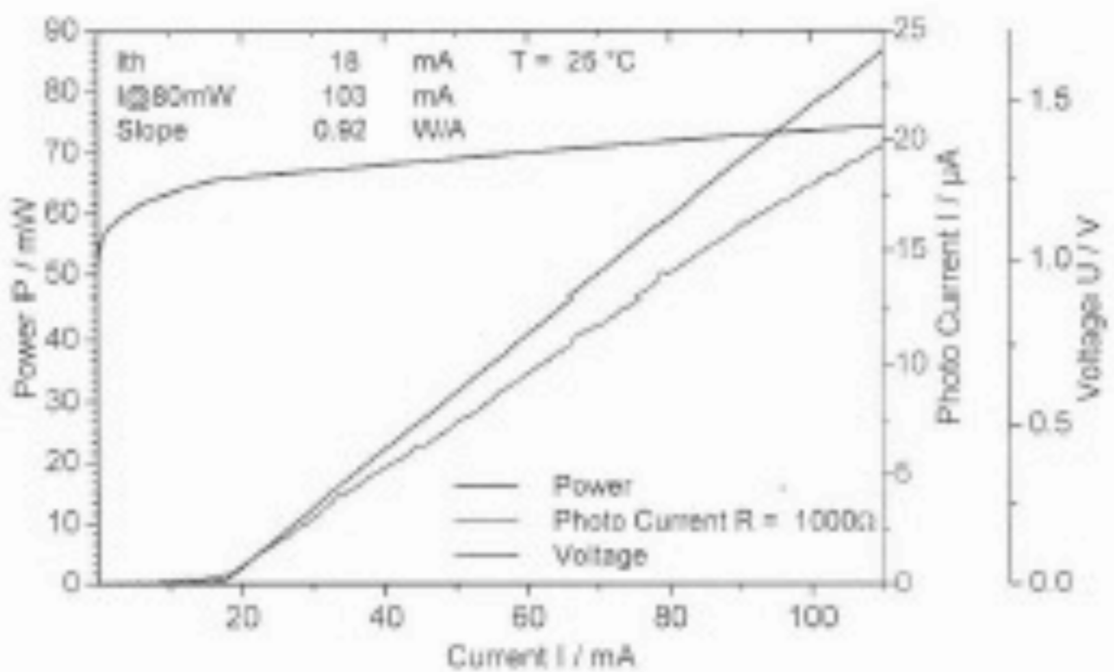
Measurement Results

Data of the Diode Laser:

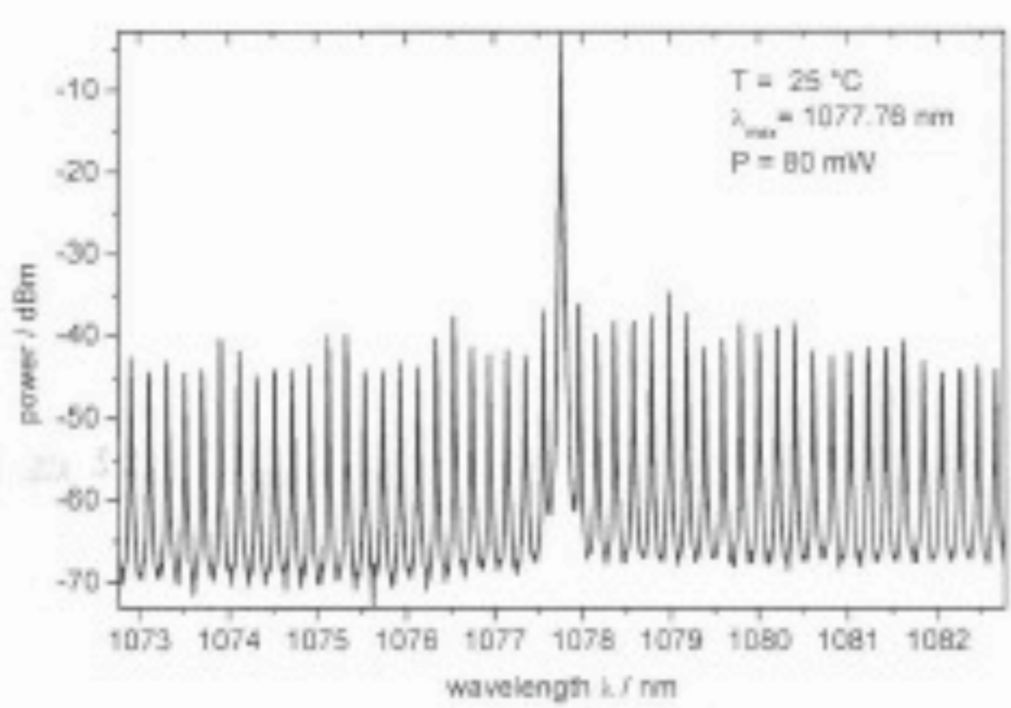
Charge	**022084** (0987/1105)	Diode	**051203**
Header	SOT	Header Number	**BA716**

Data:

P-I-characteristic:



Spectrum:



Page 2(2):

eagleyard PHOTONICS

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

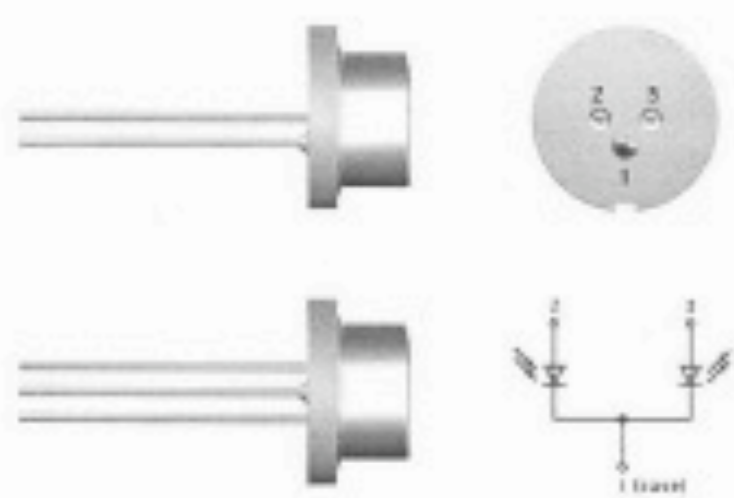
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051202**
Header	SOT	Header Number	**BA715**
λ at 80mW/nm	1079.88	Stripe Width/µm	3
Threshold Current/mA	19	Slope/ W/A	0.86
		Temperature/°C	25

Mode Structure — fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:

Packed: [illegible] 2005

Signature: ...Wiedner...........

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Page 1(2)

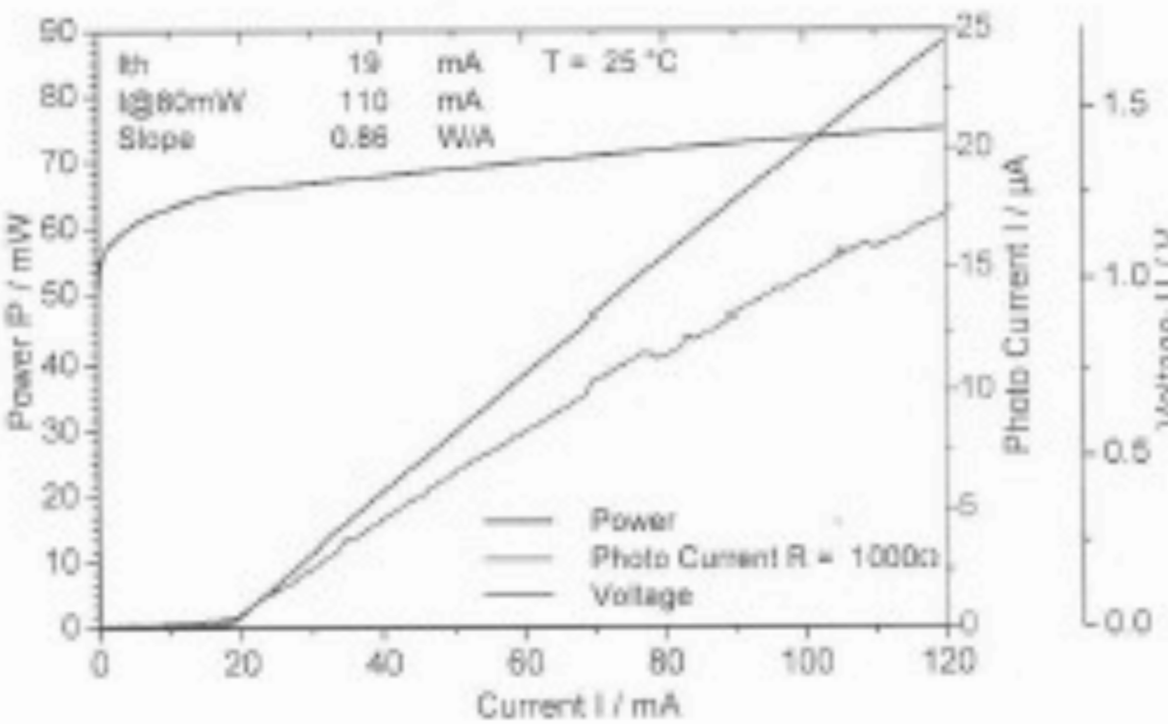
Measurement Results

Data of the Diode Laser:

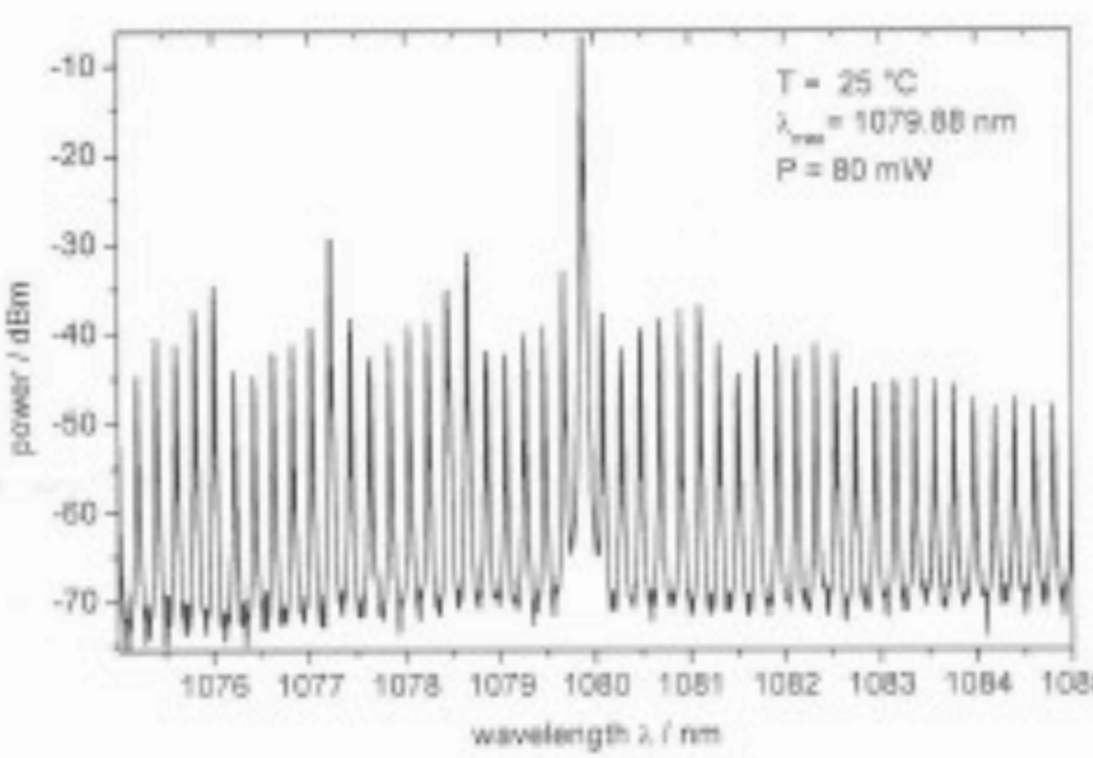
Charge	022084 (0987/1105)	Diode	051202
Header	SOT	Header Number	BA715

Data:

P-I-characteristic:



Spectrum:



Page 2(2)

eagleyard PHOTONICS

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

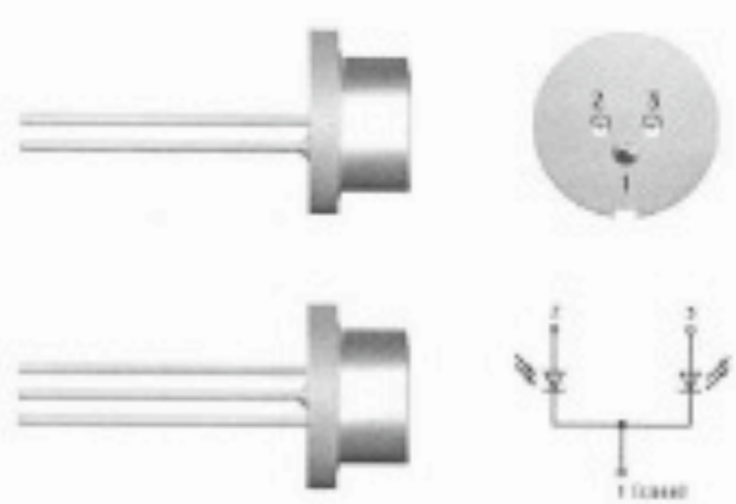
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051201**
Header	SOT	Header Number	**BA714**
λ at 80mW/nm	1078.36	Stripe Width/µm	3
Threshold Current/mA	23	Slope/ W/A	0.86
		Temperature/°C	25

Mode Structure fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:

Packed: 22 AUG. 2005

Signature: ....

http://www.eagleyard.com

Page 1(2)

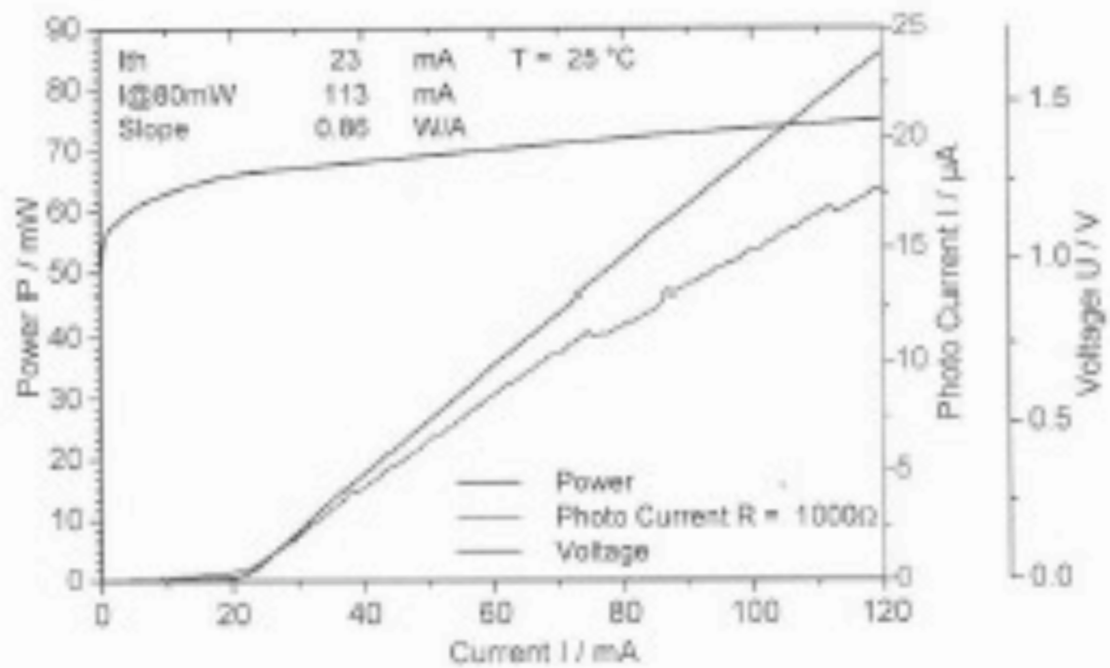
Measurement Results

Data of the Diode Laser:

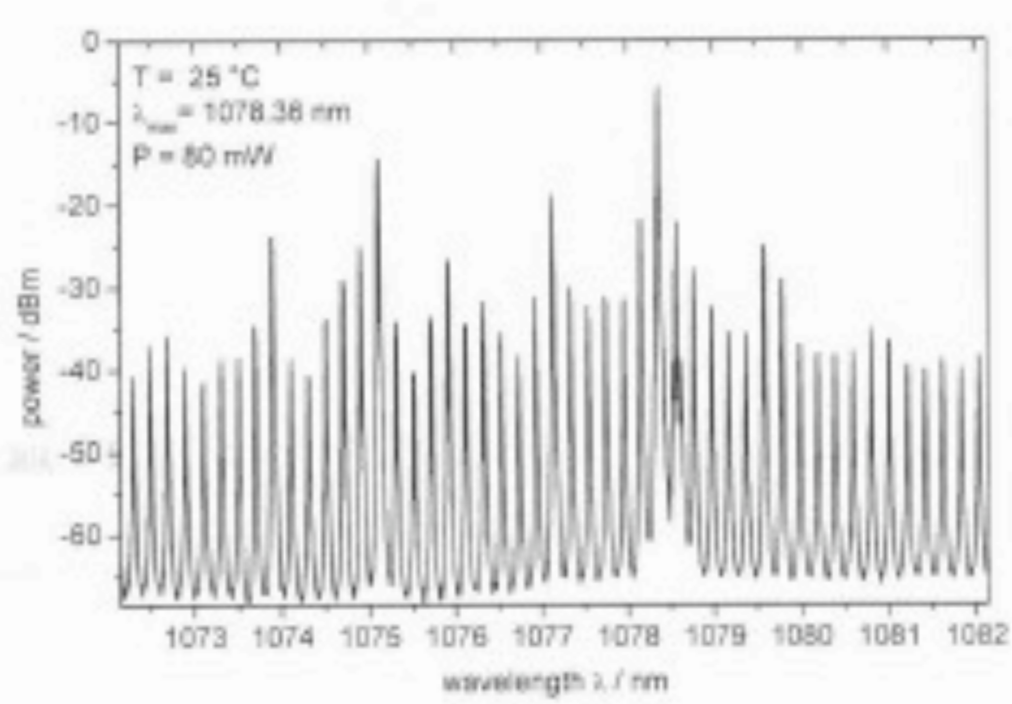
Charge	**022084** (0987/1105)	Diode	**051201**
Header	SOT	Header Number	**BA714**

Data:

P-I-characteristic:



Spectrum:



Page 2(2)

eagleyard PHOTONICS

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

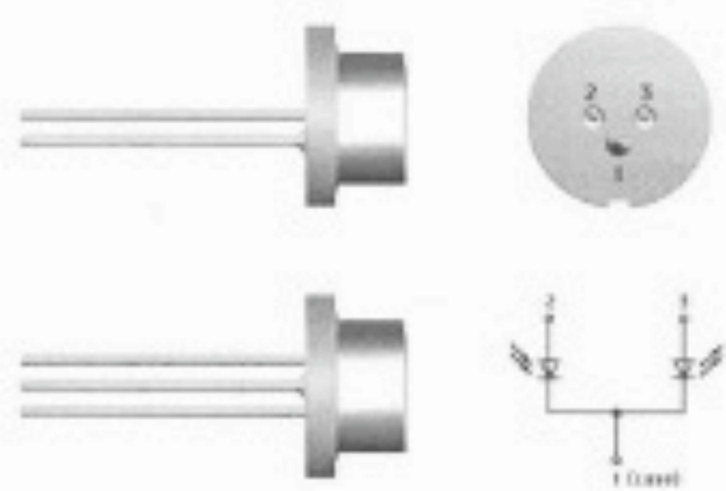
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051019**
Header	SOT	Header Number	**BA712**
λ at 80mW/nm	1081.10	Stripe Width/µm	3
Threshold Current/mA	21	Slope/ W/A	0.90
		Temperature/°C	25

Mode Structure fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:

Packed: 22 AUG. 2005

Signature: ...Wehman......

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Page 1(2):

Measurement Results

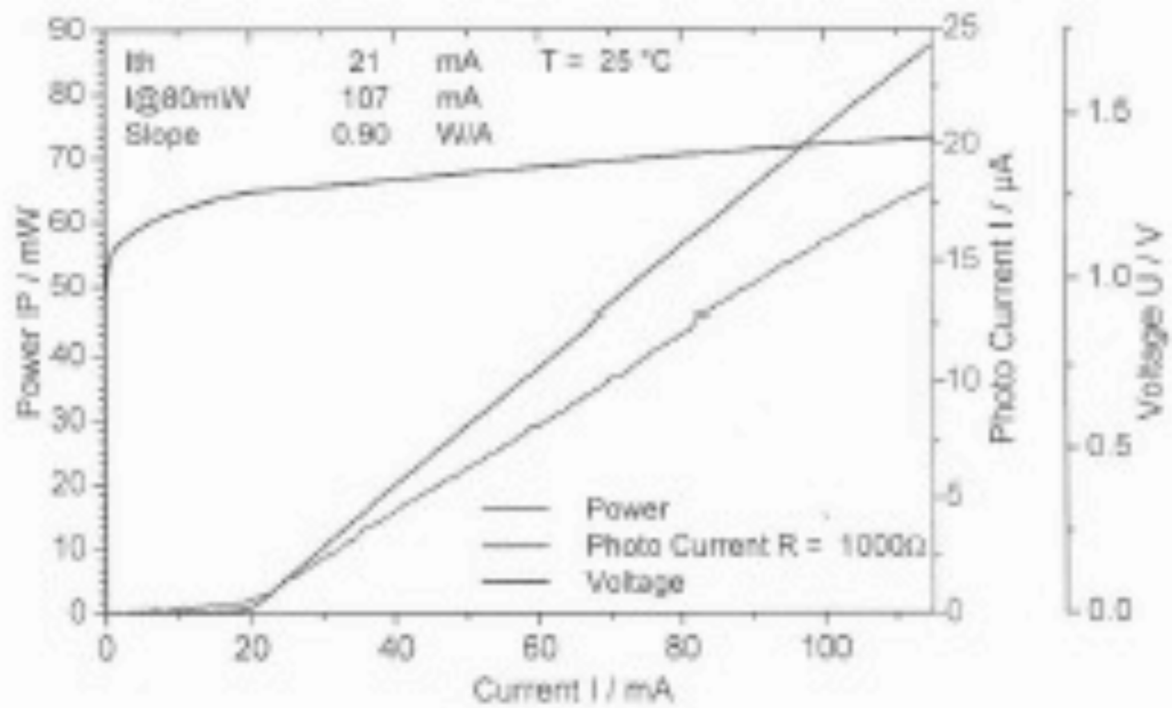
eagleyard PHOTONICS

Data of the Diode Laser:

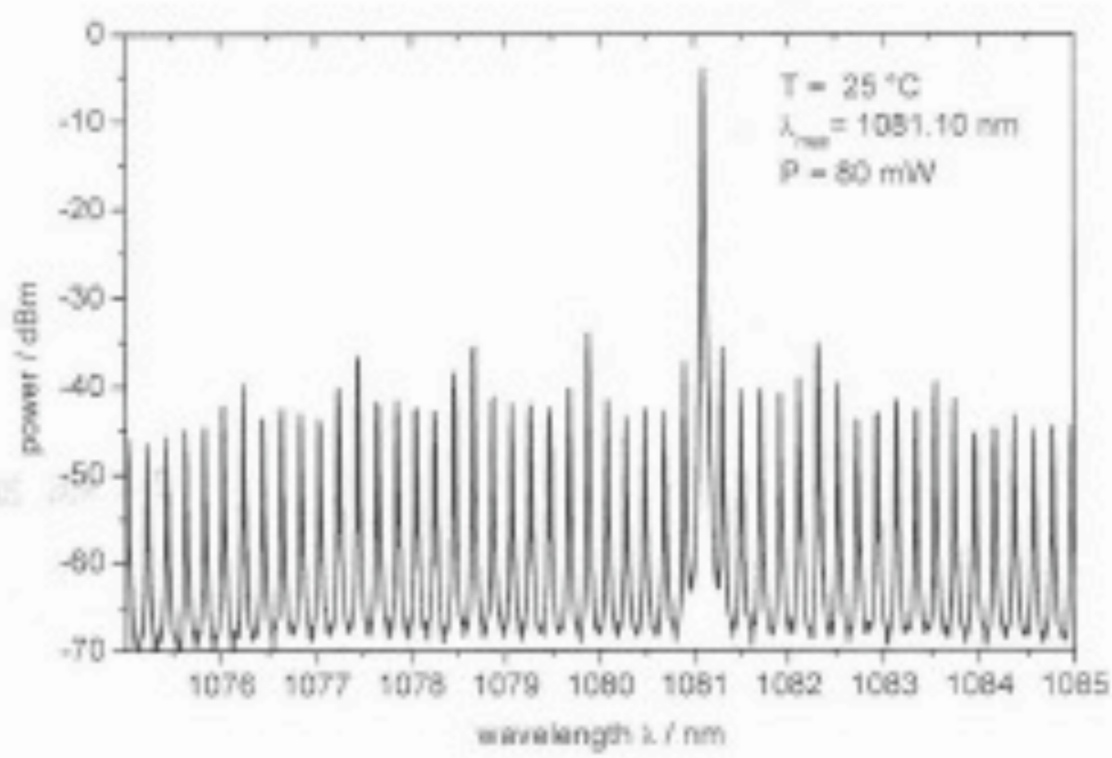
Charge	**022084** (0987/1105)	Diode	**051019**
Header	SOT	Header Number	**BA712**

Data:

P-I-characteristic:



Spectrum:



Page 2(2)

eagleyard PHOTONICS

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

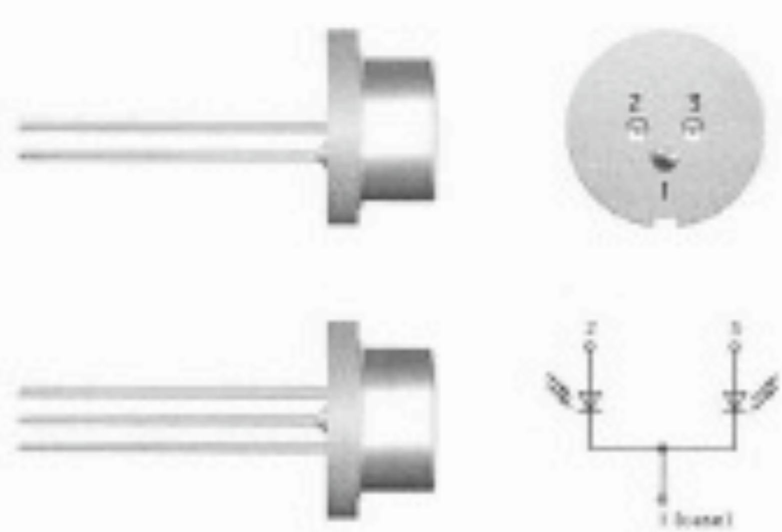
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051018**
Header	SOT	Header Number	**BA711**
λ at 80mW/nm	1081.49	Stripe Width/µm	3
Threshold Current/mA	20	Slope/ W/A	0.91
		Temperature/°C	25

Mode Structure — fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:

Packed: 22 AUG. 2005

Signature: ....

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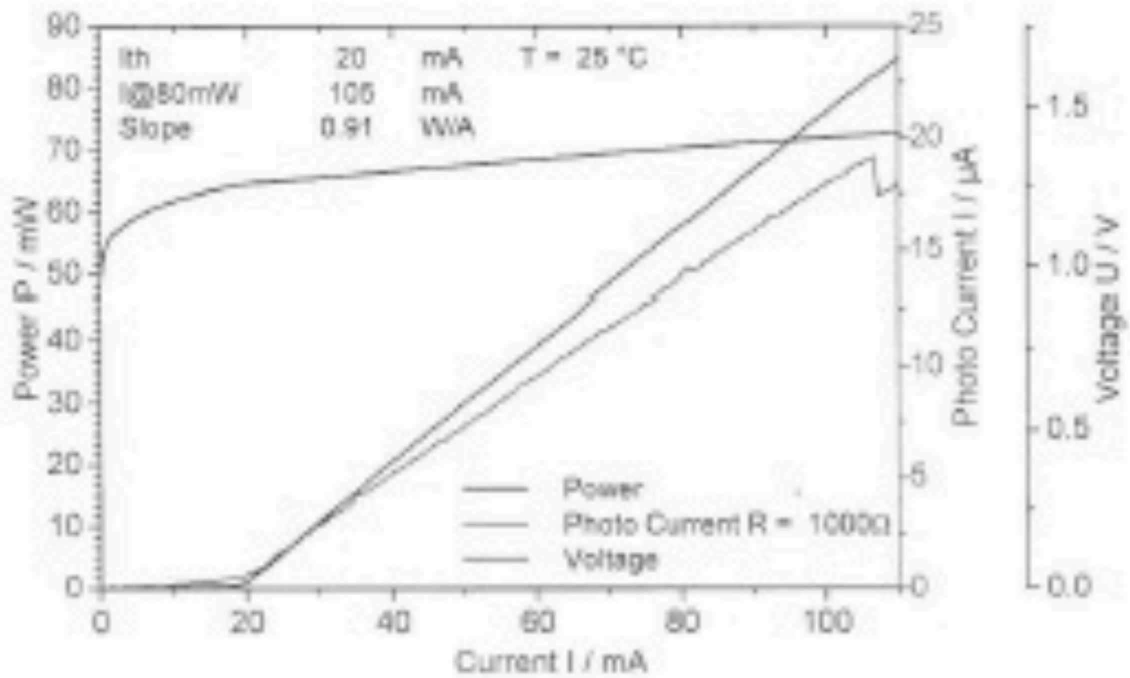
Measurement Results

Data of the Diode Laser:

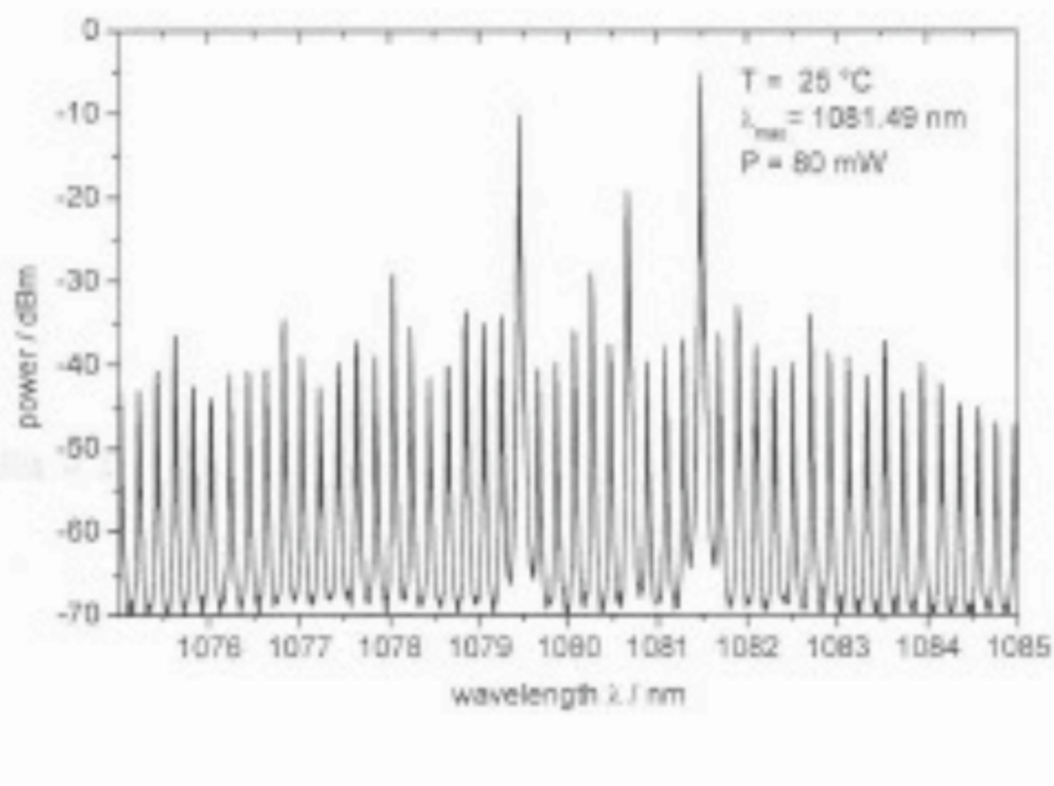
Charge	**022084** (0987/1105)	Diode	**051018**
Header	SOT	Header Number	**BA711**

Data:

P-I-characteristic:



Spectrum:



Page 2(2):

eagleyard PHOTONICS

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

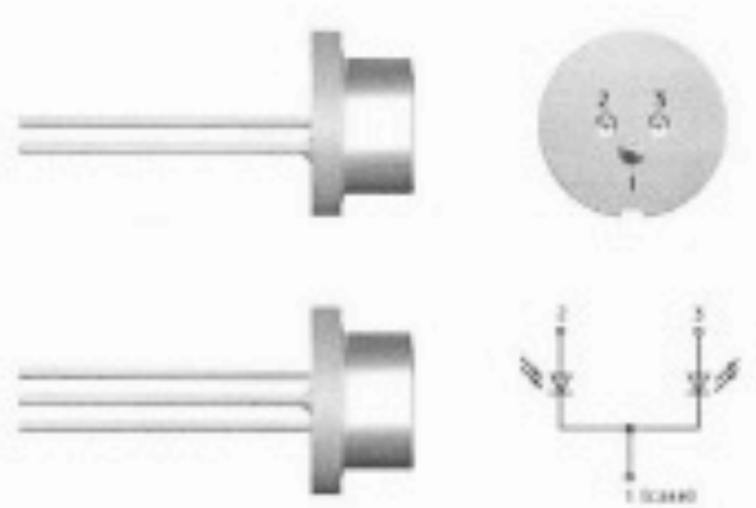
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051017**
Header	SOT	Header Number	**BA710**
λ at 80mW/nm	1080.52	Stripe Width/µm	3
Threshold Current/mA	21	Slope/ W/A	0.89
		Temperature/°C	25

Mode Structure fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:

Packed: 22 AUG. 2005

Signature: ....

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Page 1(2):

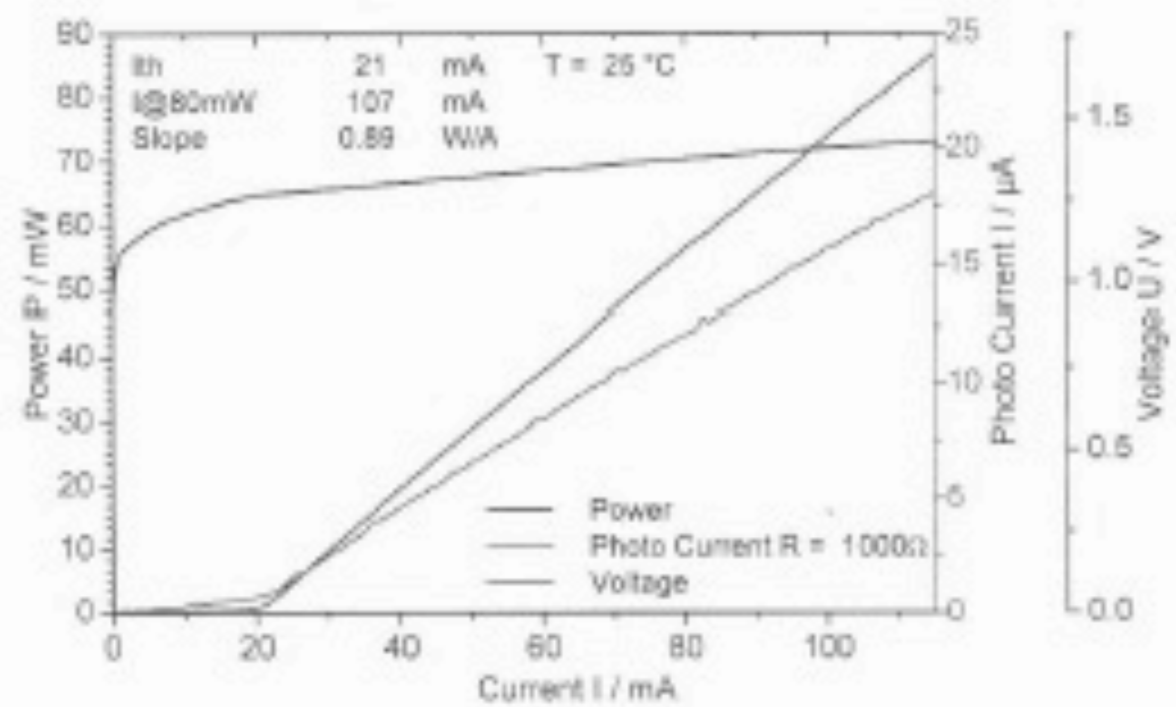
Measurement Results

Data of the Diode Laser:

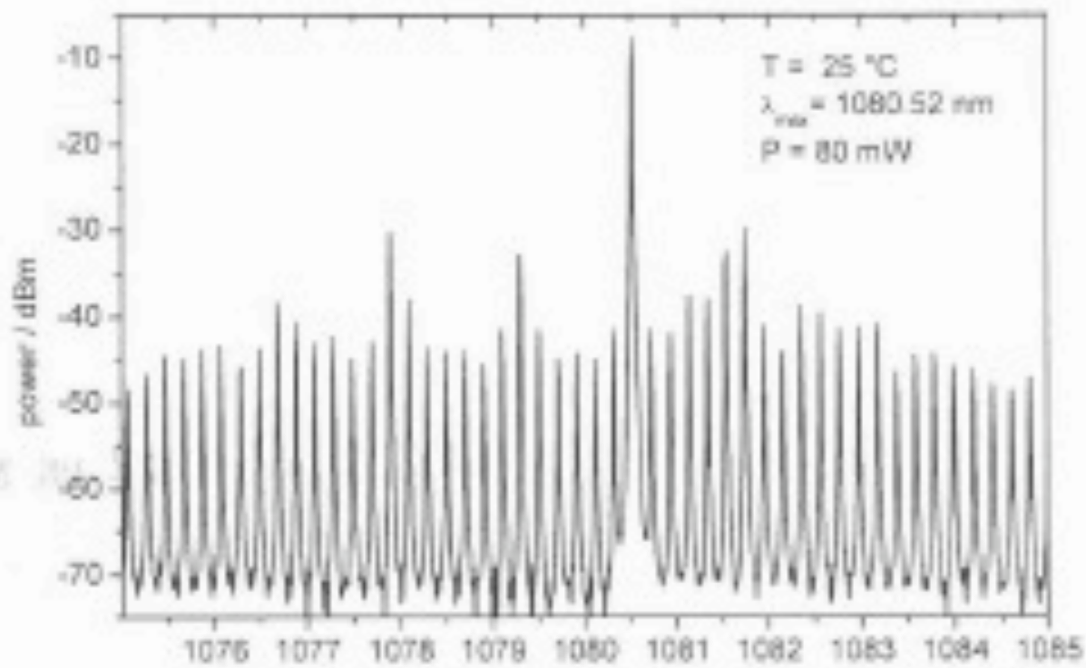
Charge	022084 (0987/1105)	Diode	051017
Header	SOT	Header Number	BA710

Data:

P-I-characteristic:



Spectrum:



Page 2(2)

eagleyard PHOTONICS

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

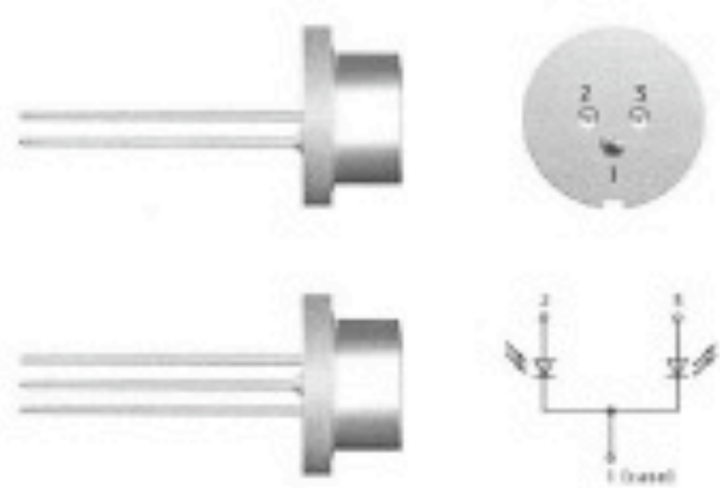
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051016**
Header	SOT	Header Number	**BA709**
λ at 80mW/nm	1081.06	Stripe Width/µm	3
Threshold Current/mA	22	Slope/ W/A	0.86
		Temperature/°C	25

Mode Structure fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:

Packed: 22 AUG. 2005

Signature: ....Wedm........

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Page 1(2)

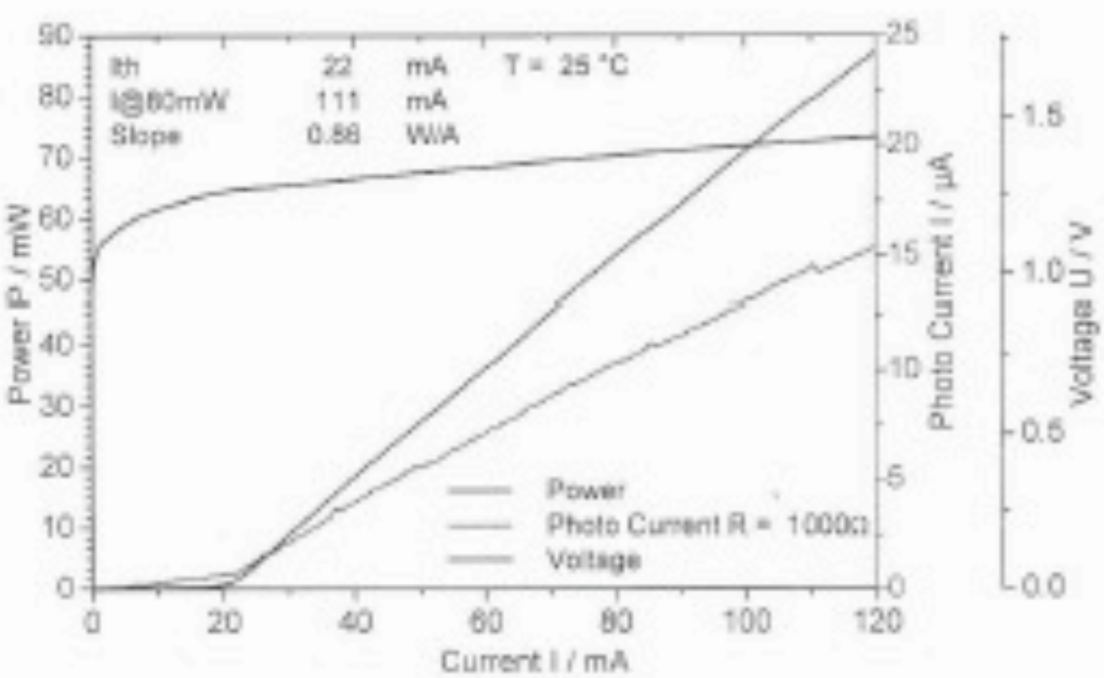
Measurement Results

Data of the Diode Laser:

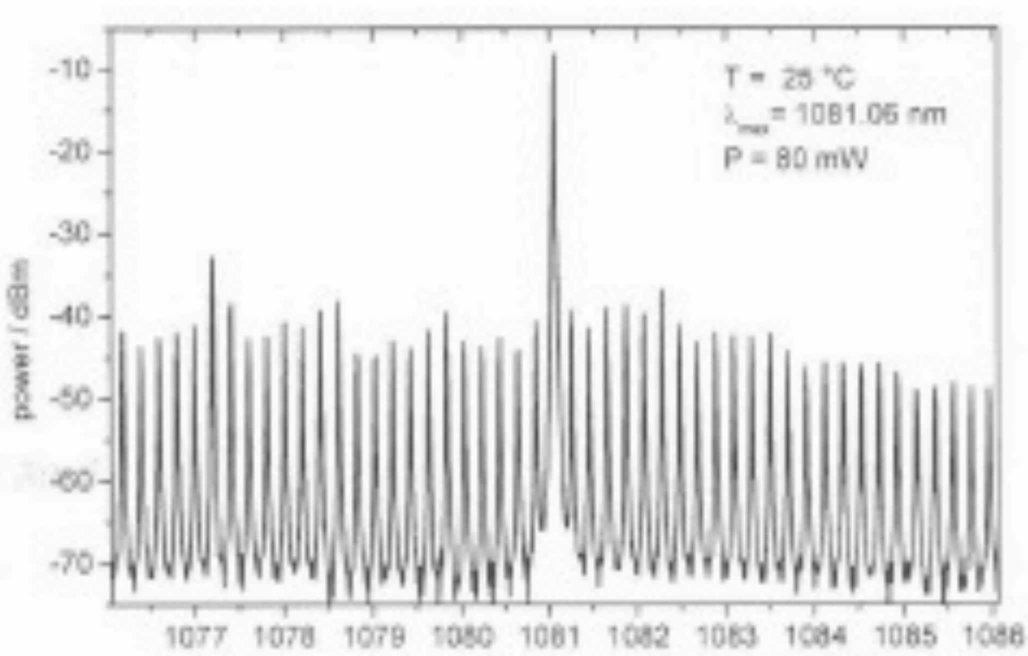
Charge	**022084** (0987/1105)	Diode	**051016**
Header	SOT	Header Number	**BA709**

Data:

P-I-characteristic:



Spectrum:



Page 2(2)

eagleyard PHOTONICS

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

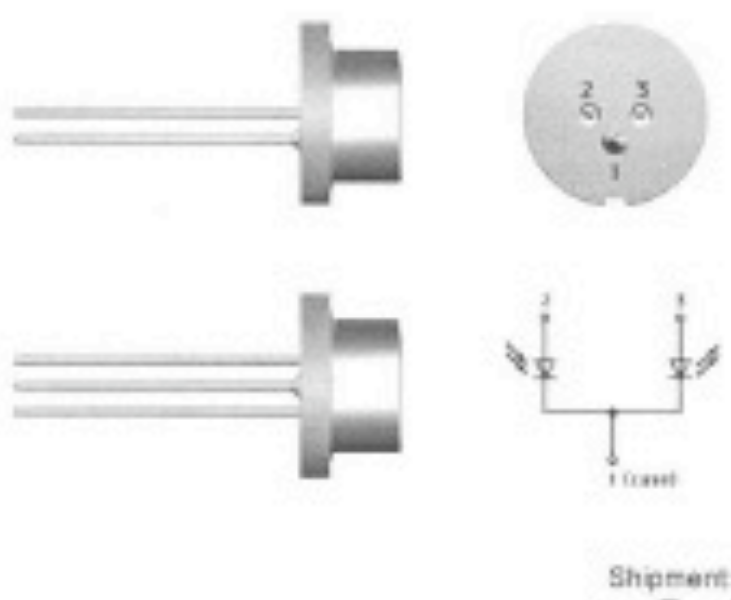
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051013**
Header	SOT	Header Number	**BA707**
λ at 80mW/nm	1080.57	Stripe Width/µm	3
Threshold Current/mA	21	Slope/ W/A	0.90
		Temperature/°C	25

Mode Structure fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:

Packed: 22 AUG. 2005

Signature: Wiedman

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Page 1(2)

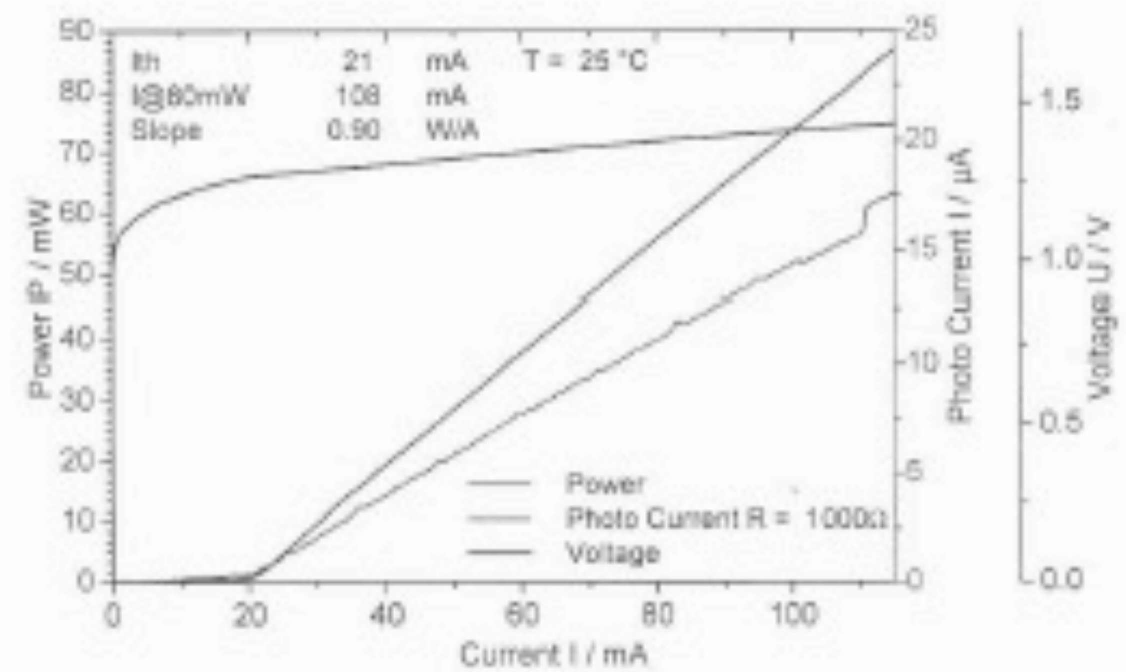
Measurement Results

Data of the Diode Laser:

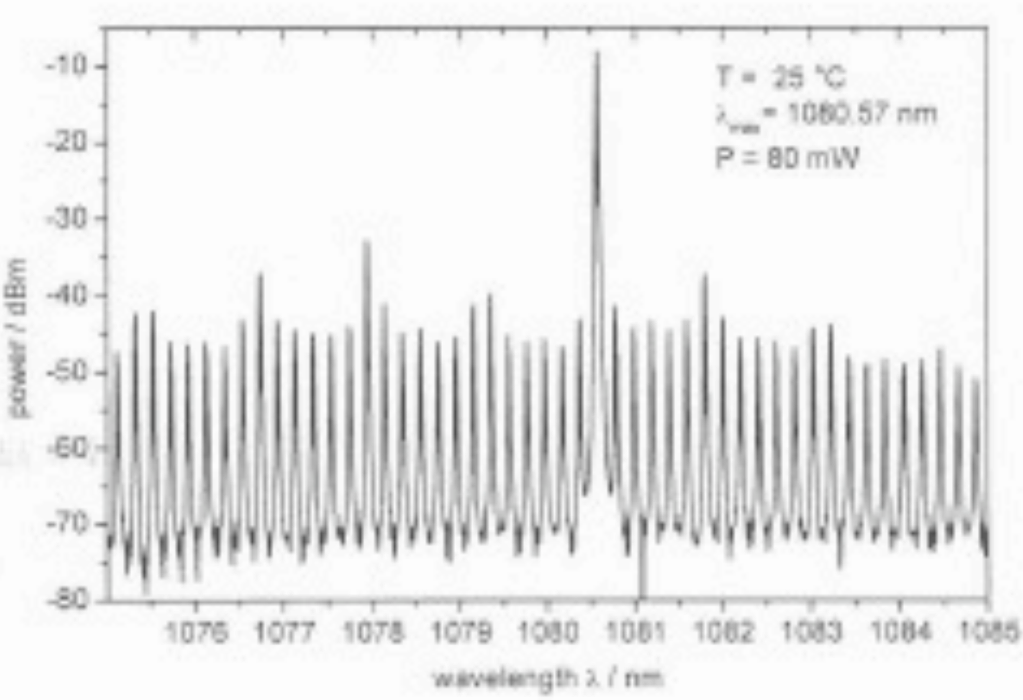
Charge	**022084** (0987/1105)	Diode	**051013**
Header	SOT	Header Number	**BA707**

Data:

P-I-characteristic:



Spectrum:



Page 2(2)

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

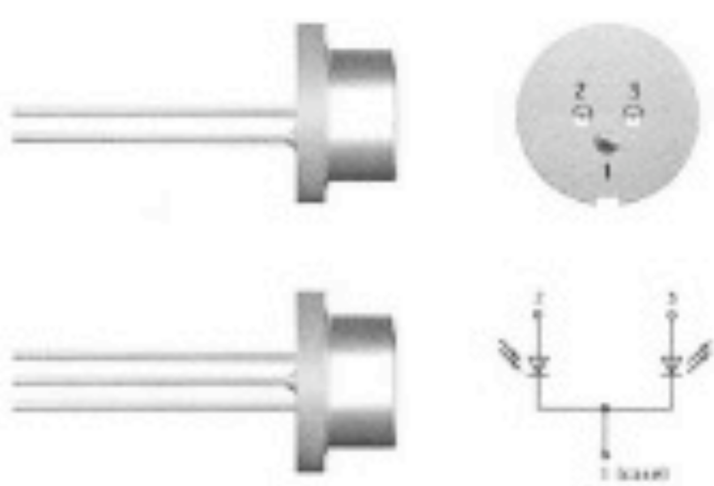
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051012**
Header	SOT	Header Number	**BA706**
λ at 80mW/nm	1082.49	Stripe Width/µm	3
Threshold Current/mA	20	Slope/ W/A	0.86
		Temperature/°C	25

Mode Structure fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:
Packed: 2 2. AUG. 2005

Signature: Wiedmer

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Page 1(2):

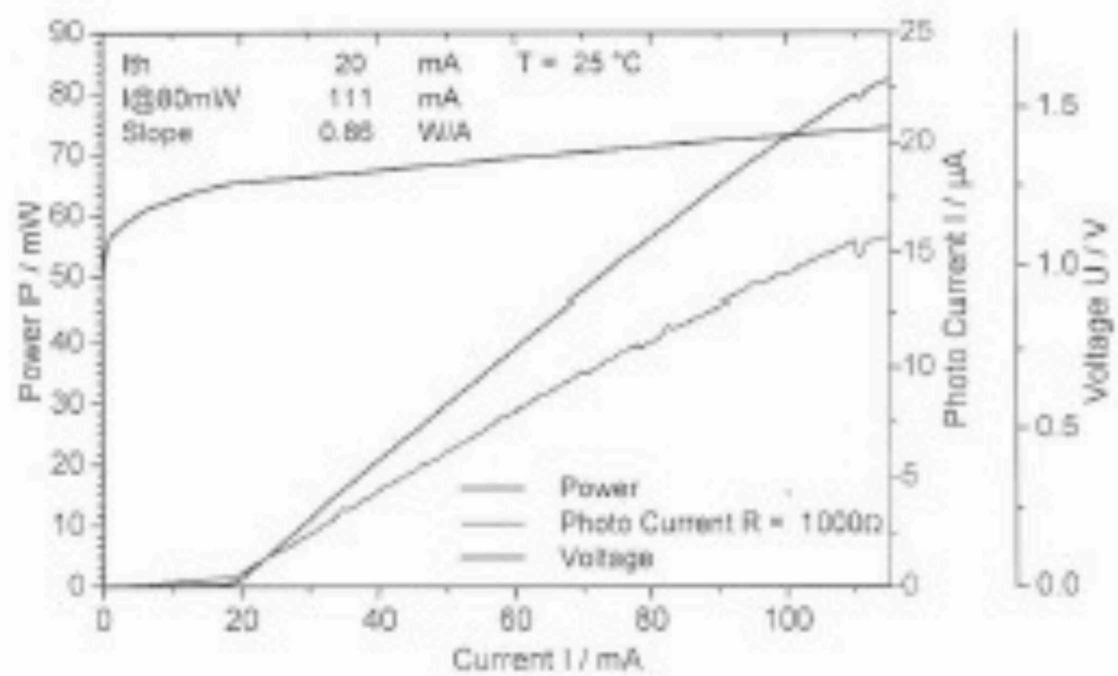
Measurement Results

Data of the Diode Laser:

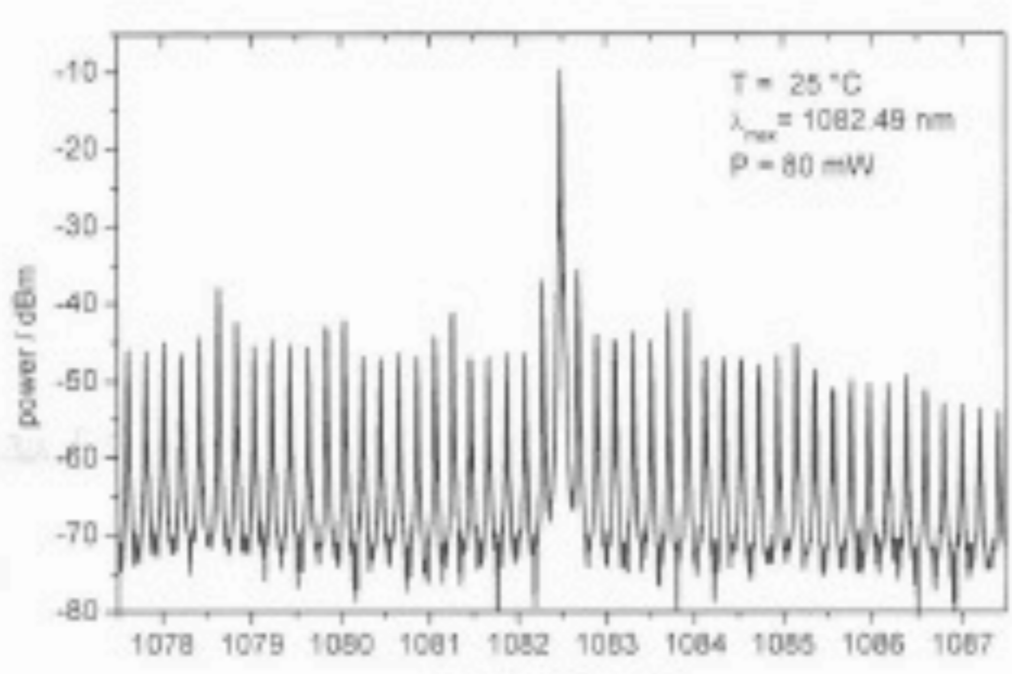
Charge	**022084** (0987/1105)	Diode	**051012**
Header	SOT	Header Number	**BA706**

Data:

P-I-characteristic:



Spectrum:



Page 2(2)

eagleyard PHOTONICS

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

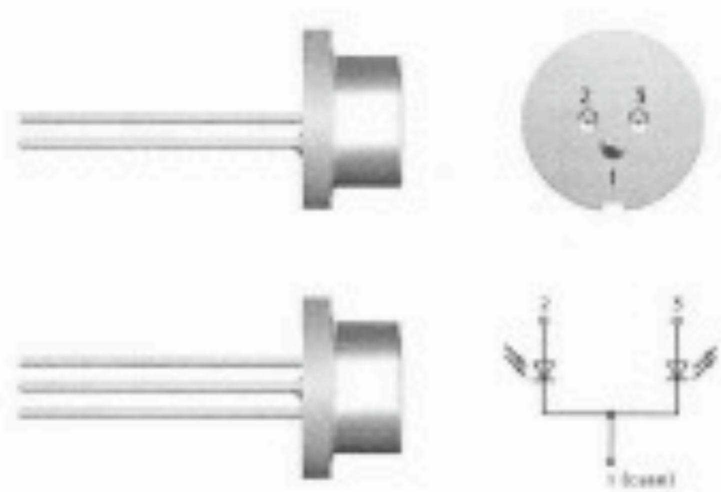
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051006**
Header	SOT	Header Number	**BA705**
λ at 80mW/nm	1078.27	Stripe Width/μm	3
Threshold Current/mA	22	Slope/ W/A	0.89
		Temperature/°C	25

Mode Structure fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:

Packed: 22 AUG. 2005

Signature: ....

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Page 1(2):

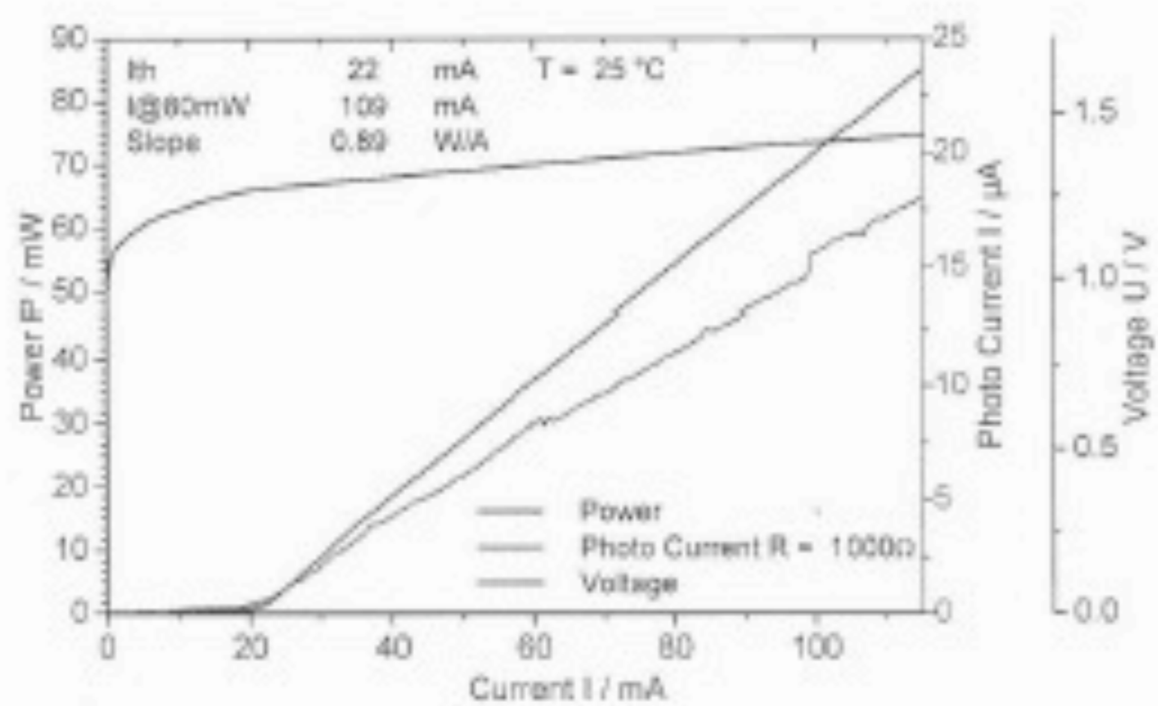
Measurement Results

Data of the Diode Laser:

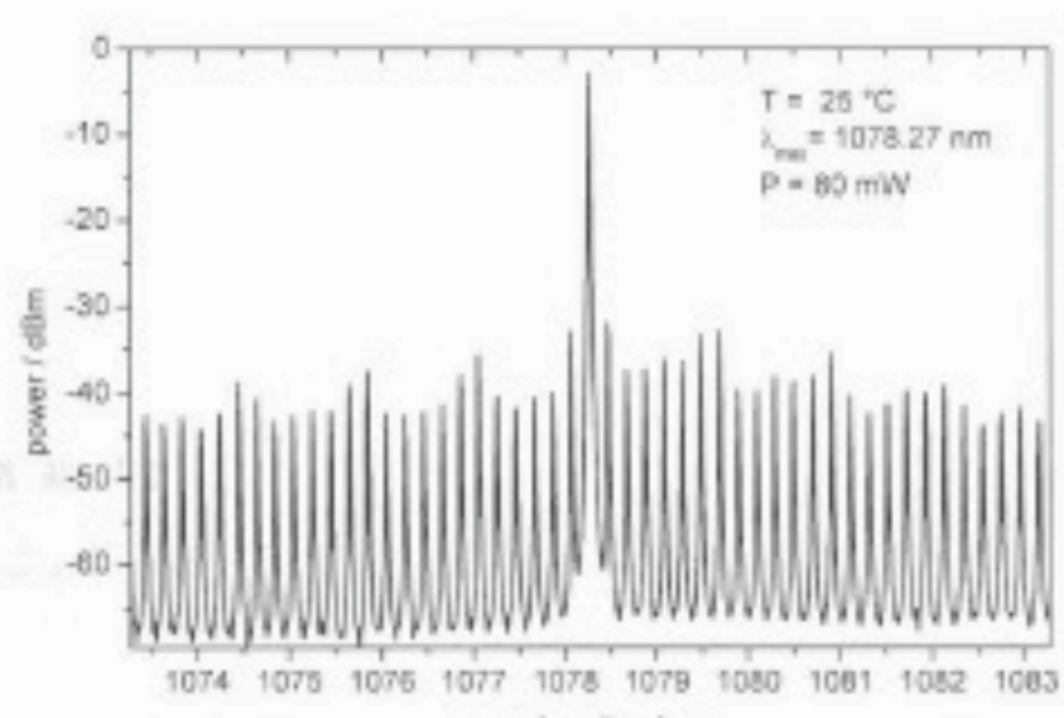
Charge	022084 (0987/1105)	Diode	051006
Header	SOT	Header Number	BA705

Data:

P-I-characteristic:



Spectrum:



Page 2(2)

eagleyard PHOTONICS

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

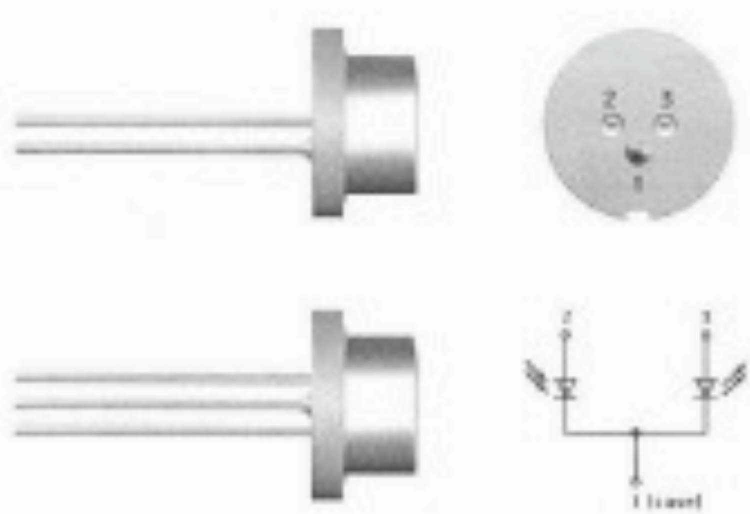
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051004**
Header	SOT	Header Number	**BA704**
λ at 80mW/nm	1078.05	Stripe Width/µm	3
Threshold Current/mA	19	Slope/ W/A	0.92
		Temperature/°C	25

Mode Structure fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:
Packed: 2 2. AUG. 2005

Signature: [illegible]

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Page 1(2)

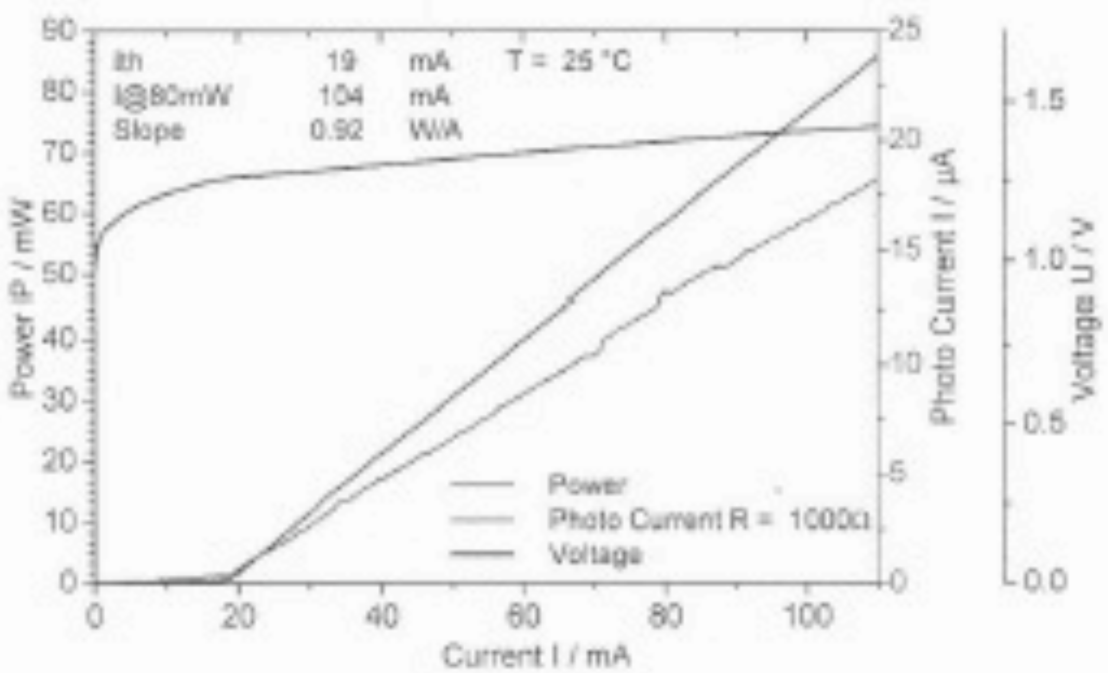
Measurement Results

Data of the Diode Laser:

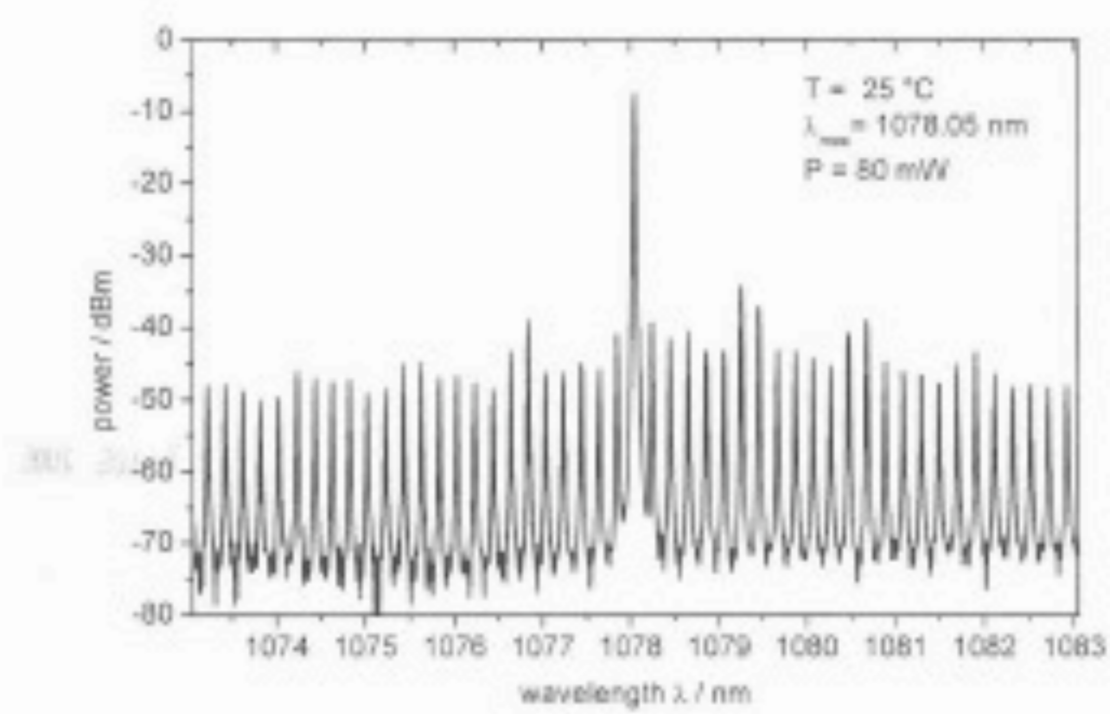
Charge	**022084** (0987/1105)	Diode	**051004**
Header	SOT	Header Number	**BA704**

Data:

P-I-characteristic:



Spectrum:



Page 2(2):

Measurement Results

Description of the Laser Type:

EYP-RWL-1080-00080-0750-SOT01-0000

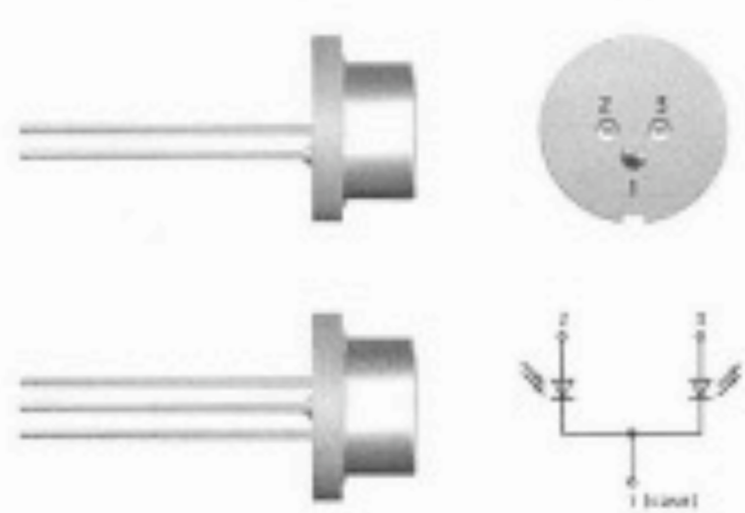
Specific Data of the Diode Laser:

Charge	**022084** (0987/1105)	Diode	**051003**
Header	SOT	Header Number	**BA703**
λ at 80mW/nm	1077.39	Stripe Width/µm	3
Threshold Current/mA	19	Slope/ W/A	0.91
		Temperature/°C	25

Mode Structure fundamental mode

Laser Class 3B safety standard

Header (rear view):



Shipment:

Packed: 22 AUG. 2005

Signature: ....

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Page 1(2):

Measurement Results

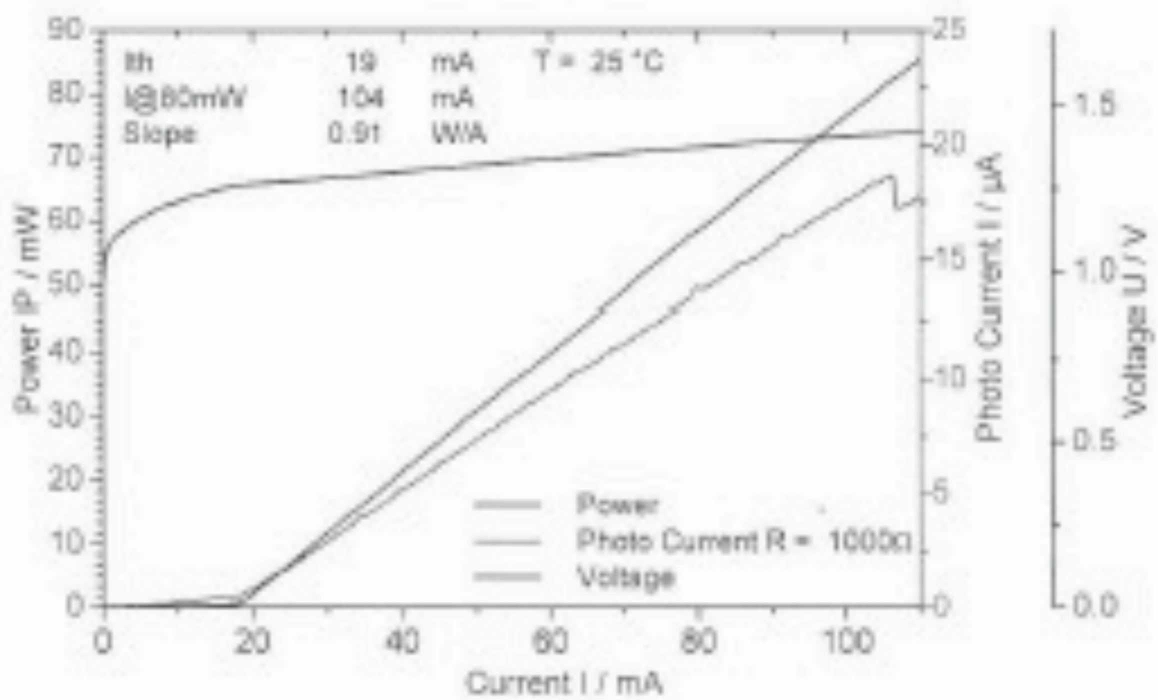
eagleyard PHOTONICS

Data of the Diode Laser:

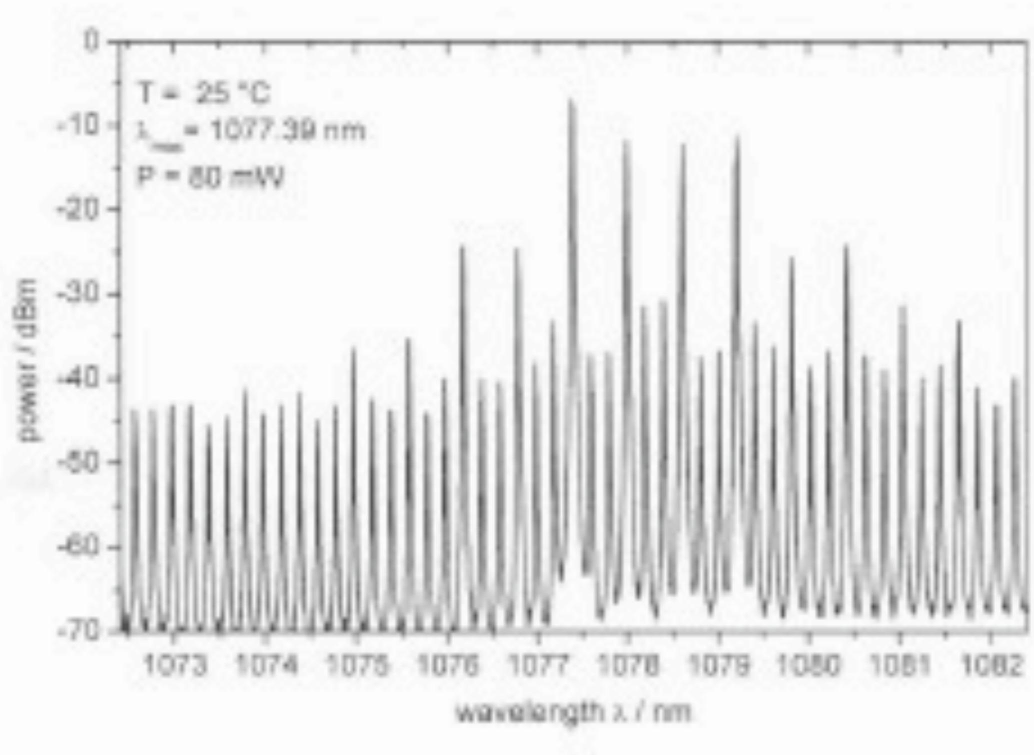
Charge	**022084** (0987/1105)	Diode	**051003**
Header	SOT	Header Number	**BA703**

Data:

P-I-characteristic:



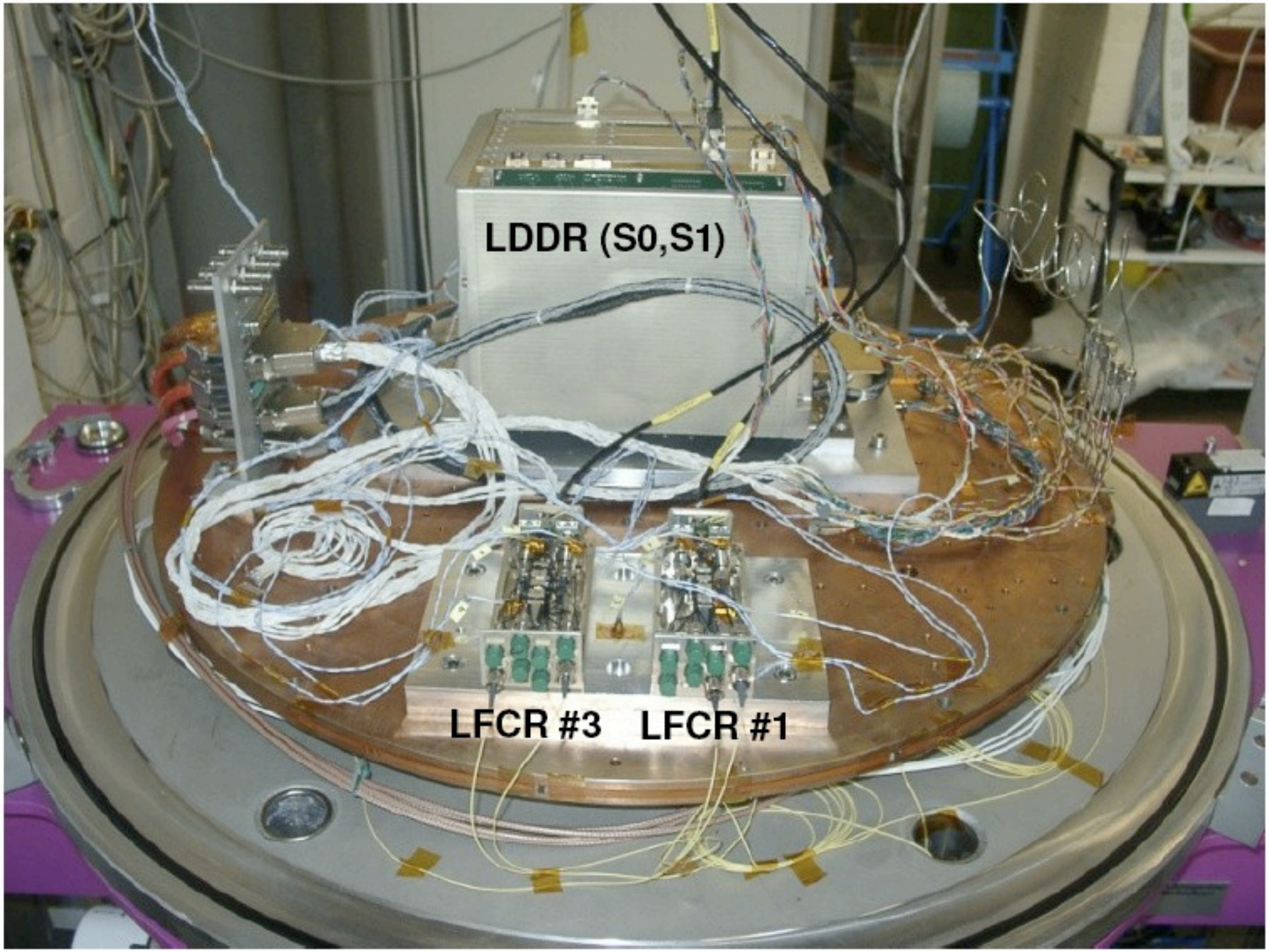
Spectrum:

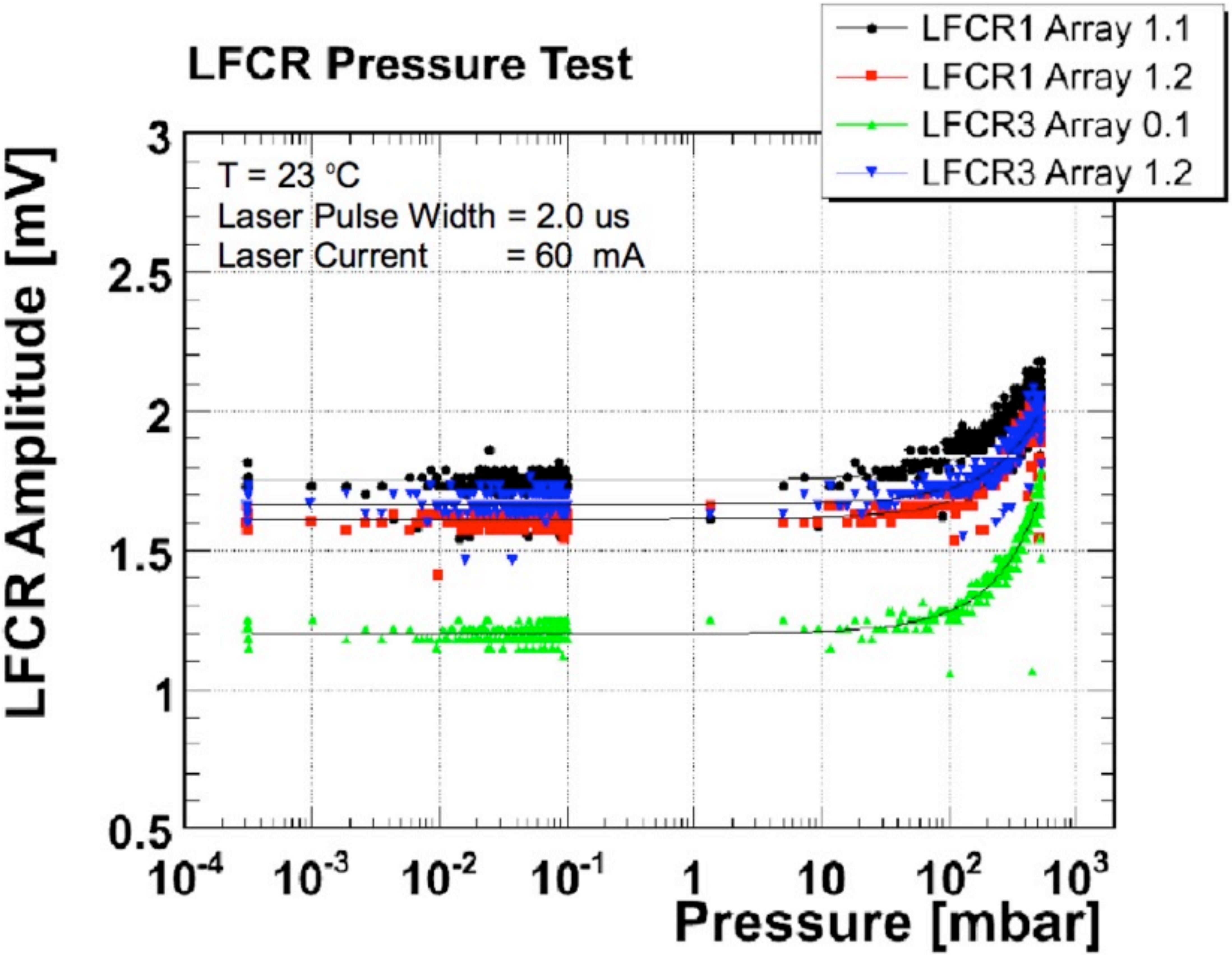


Page 2(2):

LFCRs Pressure dependence Test

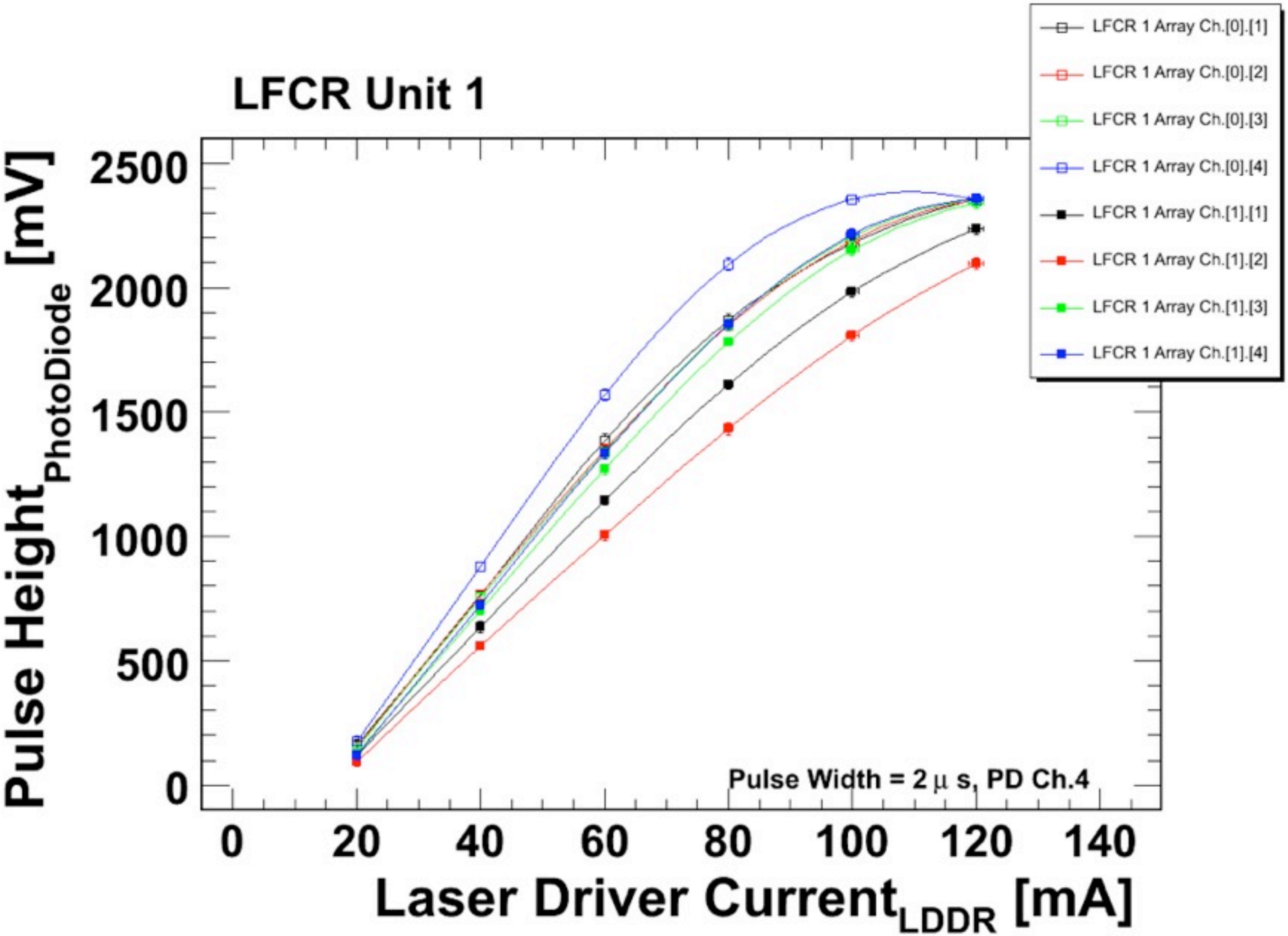
LFCR Pressure Dependence Test 07.02.2008

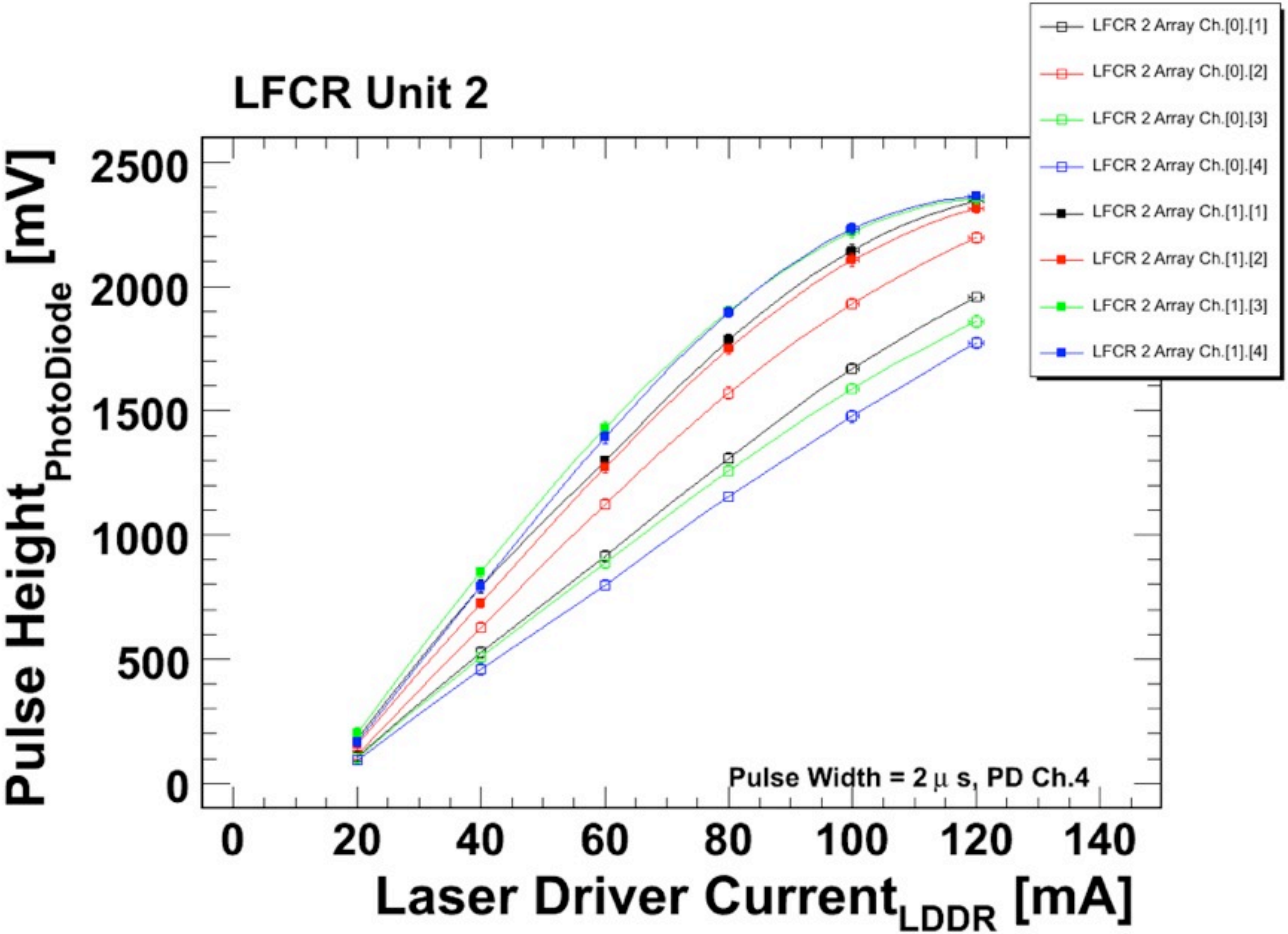




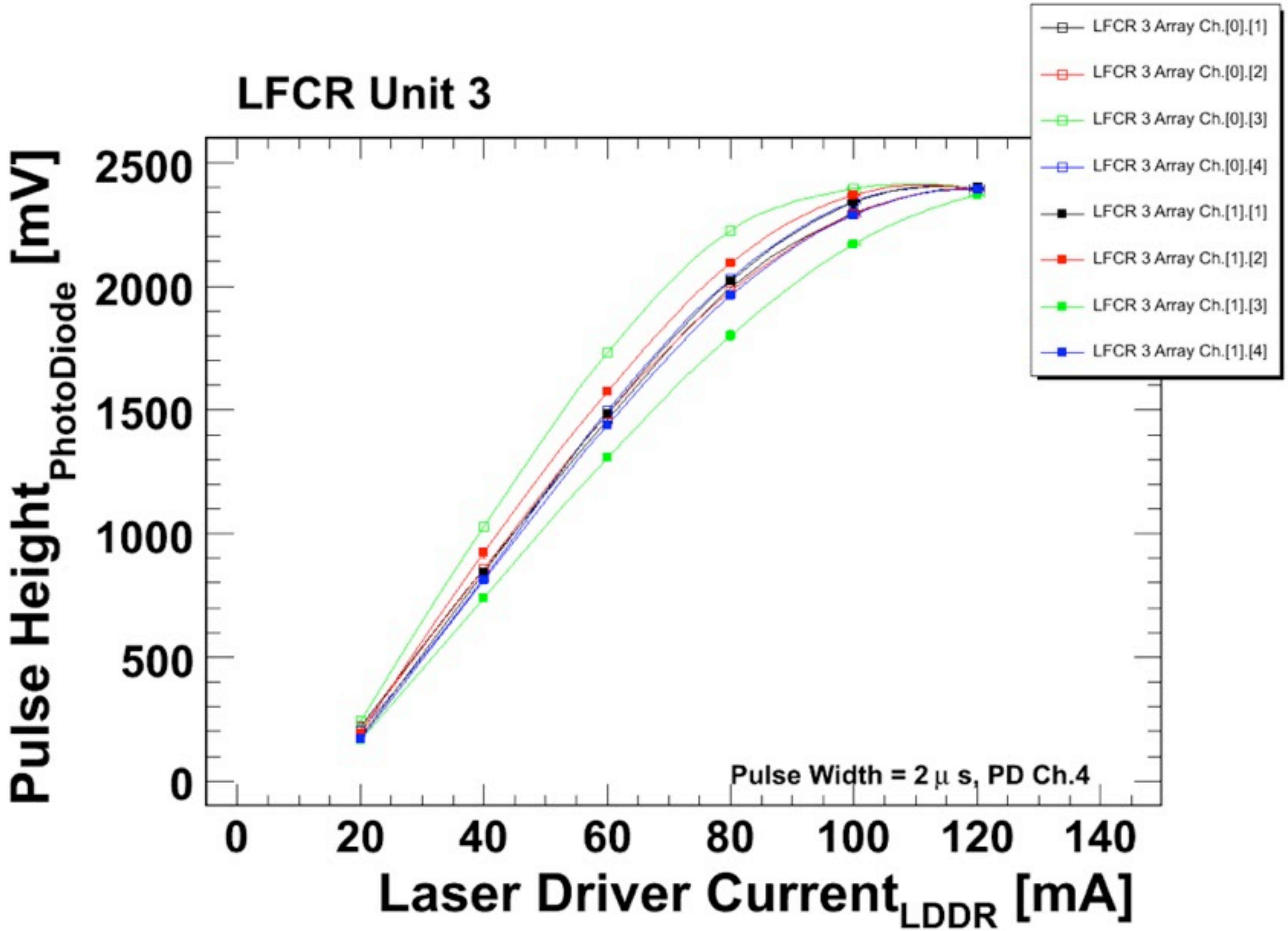
Laser output drops down between 15 ~ 30 % at high vacuum conditions

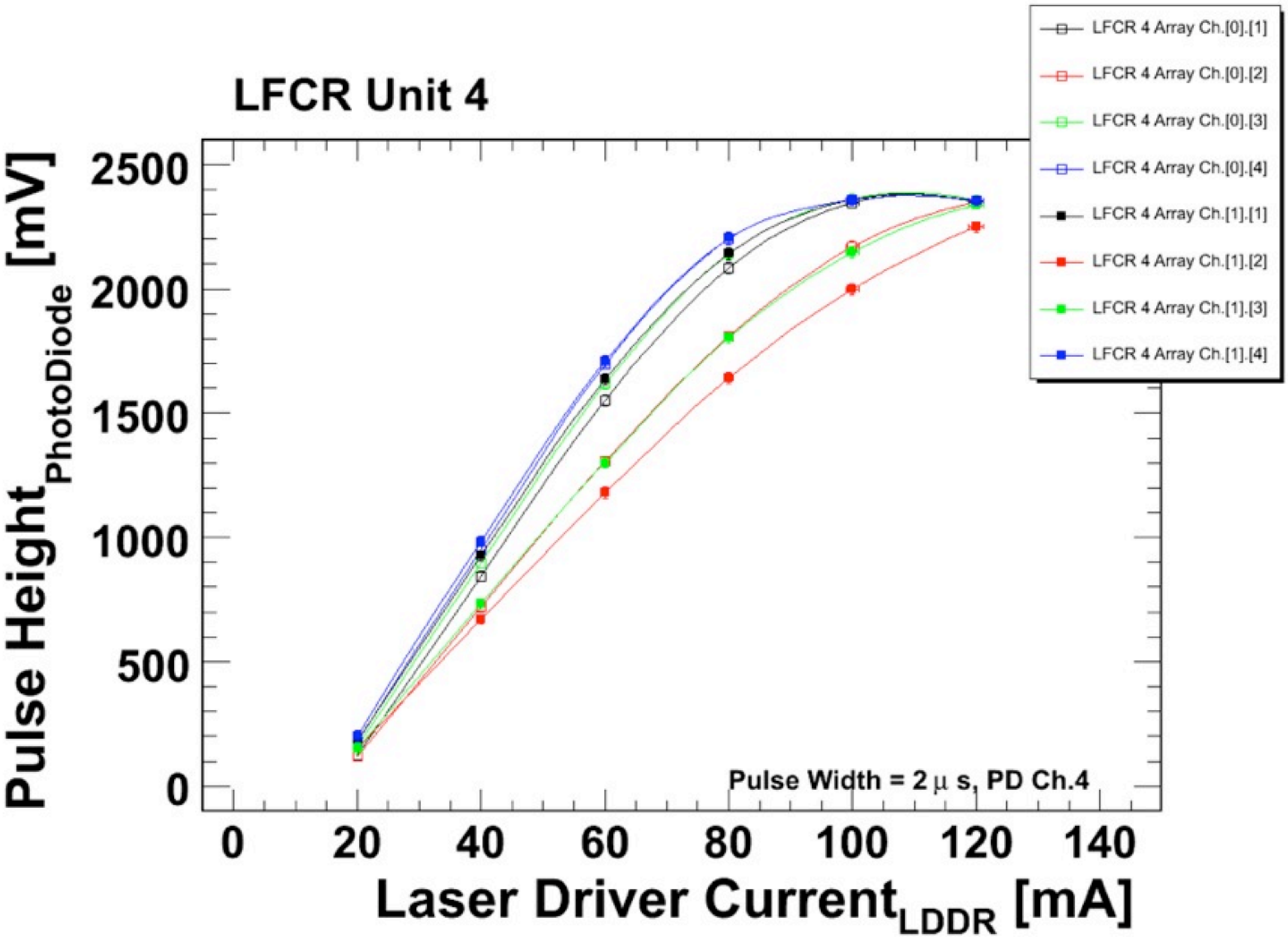
Flight LFCR Calibration with Photo-Diode

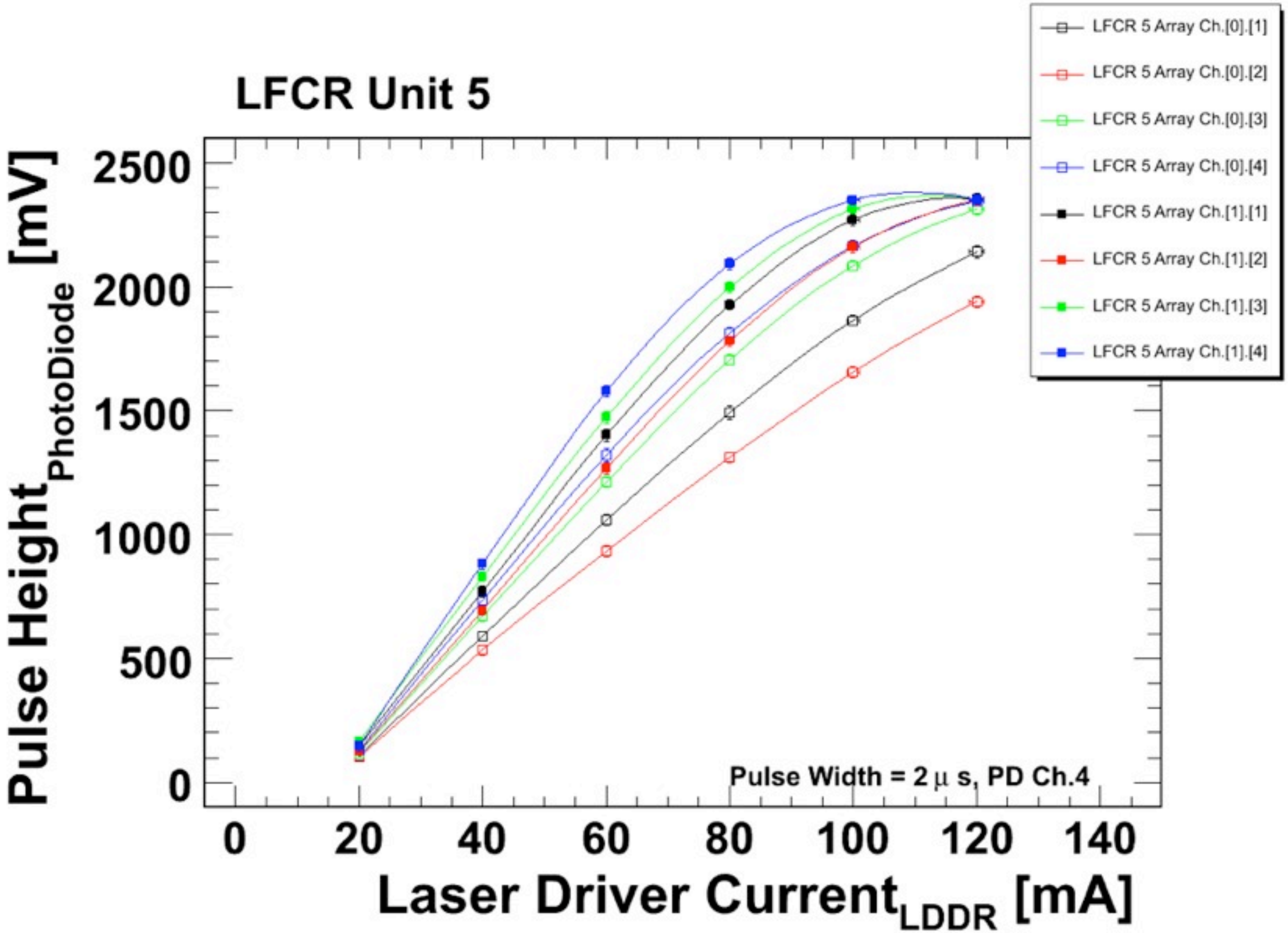

LFCR Unit 1
Pulse Height$_{PhotoDiode}$ [mV]
Laser Driver Current$_{LDDR}$ [mA]
Pulse Width = 2 μ s, PD Ch.4
LFCR 1 Array Ch.[0].[1]
LFCR 1 Array Ch.[0].[2]
LFCR 1 Array Ch.[0].[3]
LFCR 1 Array Ch.[0].[4]
LFCR 1 Array Ch.[1].[1]
LFCR 1 Array Ch.[1].[2]
LFCR 1 Array Ch.[1].[3]
LFCR 1 Array Ch.[1].[4]
0
500
1000
1500
2000
2500
0
20
40
60
80
100
120
140



LFCR Unit 2
LFCR 2 Array Ch.[0].[1]
LFCR 2 Array Ch.[0].[2]
LFCR 2 Array Ch.[0].[3]
LFCR 2 Array Ch.[0].[4]
LFCR 2 Array Ch.[1].[1]
LFCR 2 Array Ch.[1].[2]
LFCR 2 Array Ch.[1].[3]
LFCR 2 Array Ch.[1].[4]
Pulse Height$_{PhotoDiode}$ [mV]
2500
2000
1500
1000
500
0
Pulse Width = 2 μ s, PD Ch.4
0
20
40
60
80
100
120
140
Laser Driver Current$_{LDDR}$ [mA]

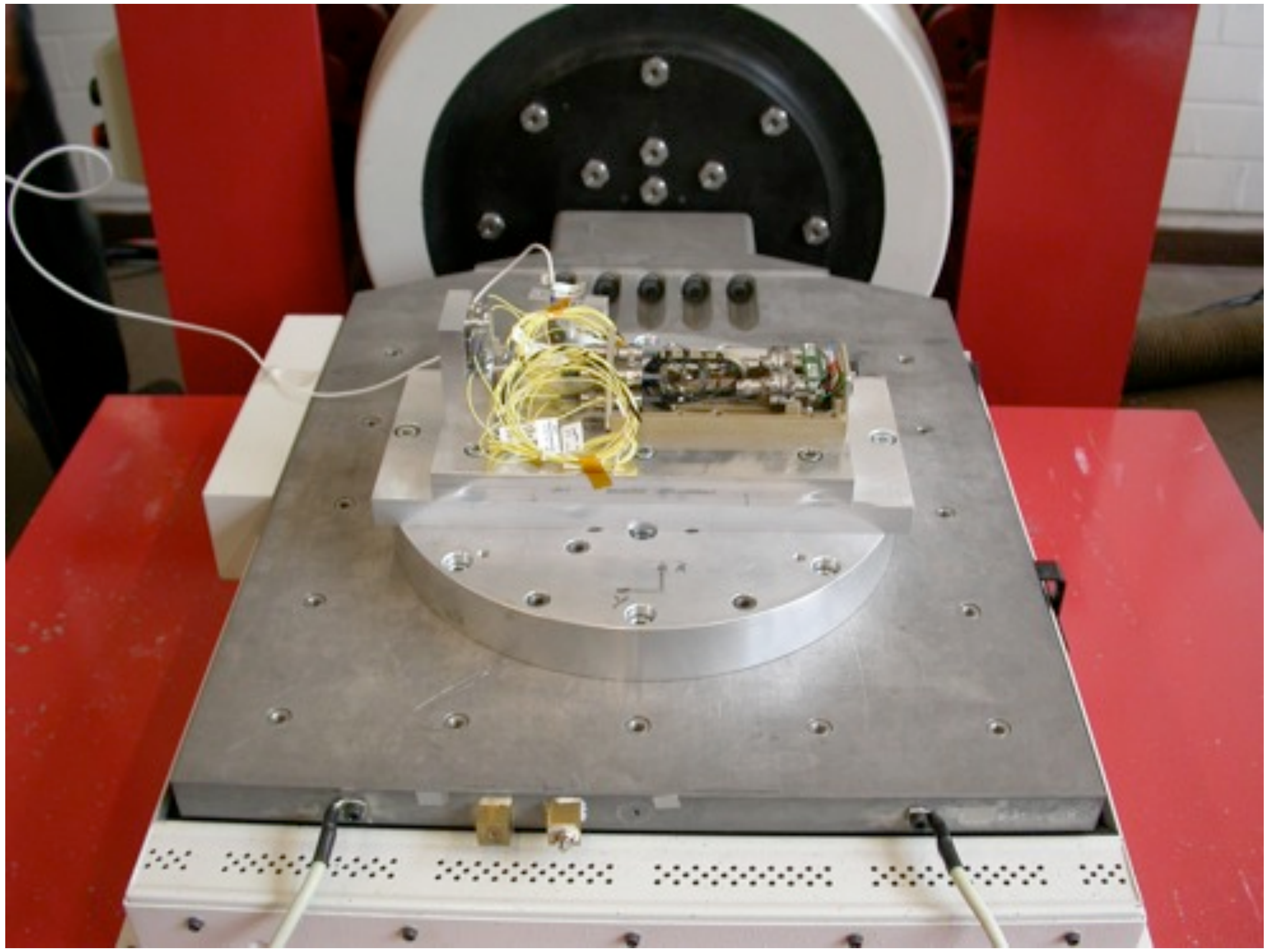

LFCR Unit 3
Pulse Height$_{PhotoDiode}$ [mV]
Laser Driver Current$_{LDDR}$ [mA]
Pulse Width = 2 μ s, PD Ch.4
LFCR 3 Array Ch.[0].[1]
LFCR 3 Array Ch.[0].[2]
LFCR 3 Array Ch.[0].[3]
LFCR 3 Array Ch.[0].[4]
LFCR 3 Array Ch.[1].[1]
LFCR 3 Array Ch.[1].[2]
LFCR 3 Array Ch.[1].[3]
LFCR 3 Array Ch.[1].[4]
0
500
1000
1500
2000
2500
0
20
40
60
80
100
120
140

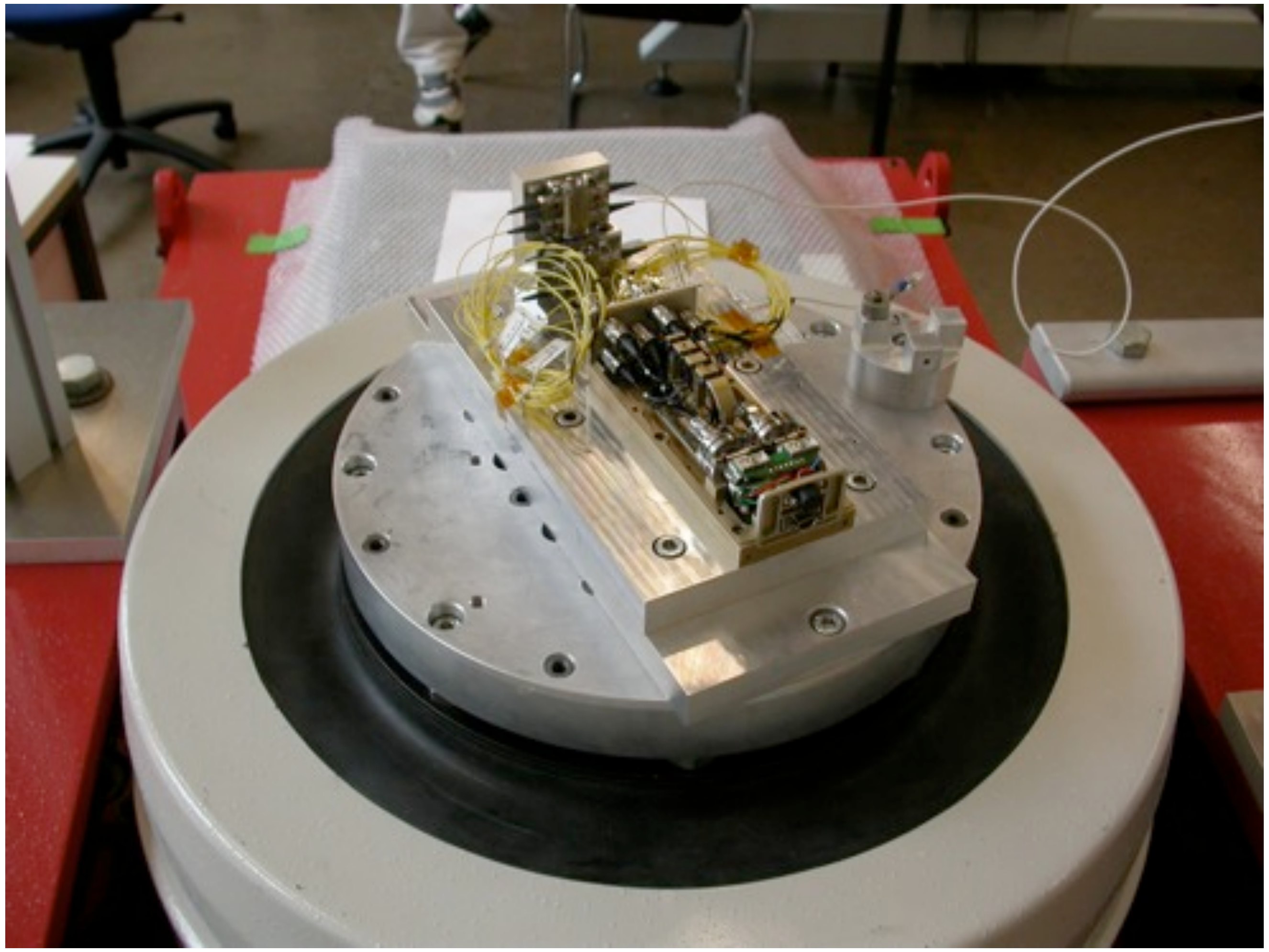

LFCR Unit 4
Pulse Height$_{PhotoDiode}$ [mV]
Laser Driver Current$_{LDDR}$ [mA]
0
500
1000
1500
2000
2500
0
20
40
60
80
100
120
140
LFCR 4 Array Ch.[0].[1]
LFCR 4 Array Ch.[0].[2]
LFCR 4 Array Ch.[0].[3]
LFCR 4 Array Ch.[0].[4]
LFCR 4 Array Ch.[1].[1]
LFCR 4 Array Ch.[1].[2]
LFCR 4 Array Ch.[1].[3]
LFCR 4 Array Ch.[1].[4]
Pulse Width = 2 μ s, PD Ch.4


LFCR Unit 5
LFCR 5 Array Ch.[0].[1]
LFCR 5 Array Ch.[0].[2]
LFCR 5 Array Ch.[0].[3]
LFCR 5 Array Ch.[0].[4]
LFCR 5 Array Ch.[1].[1]
LFCR 5 Array Ch.[1].[2]
LFCR 5 Array Ch.[1].[3]
LFCR 5 Array Ch.[1].[4]
Pulse Height PhotoDiode [mV]
2500
2000
1500
1000
500
0
Pulse Width = 2 μ s, PD Ch.4
0
20
40
60
80
100
120
140
Laser Driver Current LDDR [mA]

LFCRs Space Qualification Test (29/04/2008)

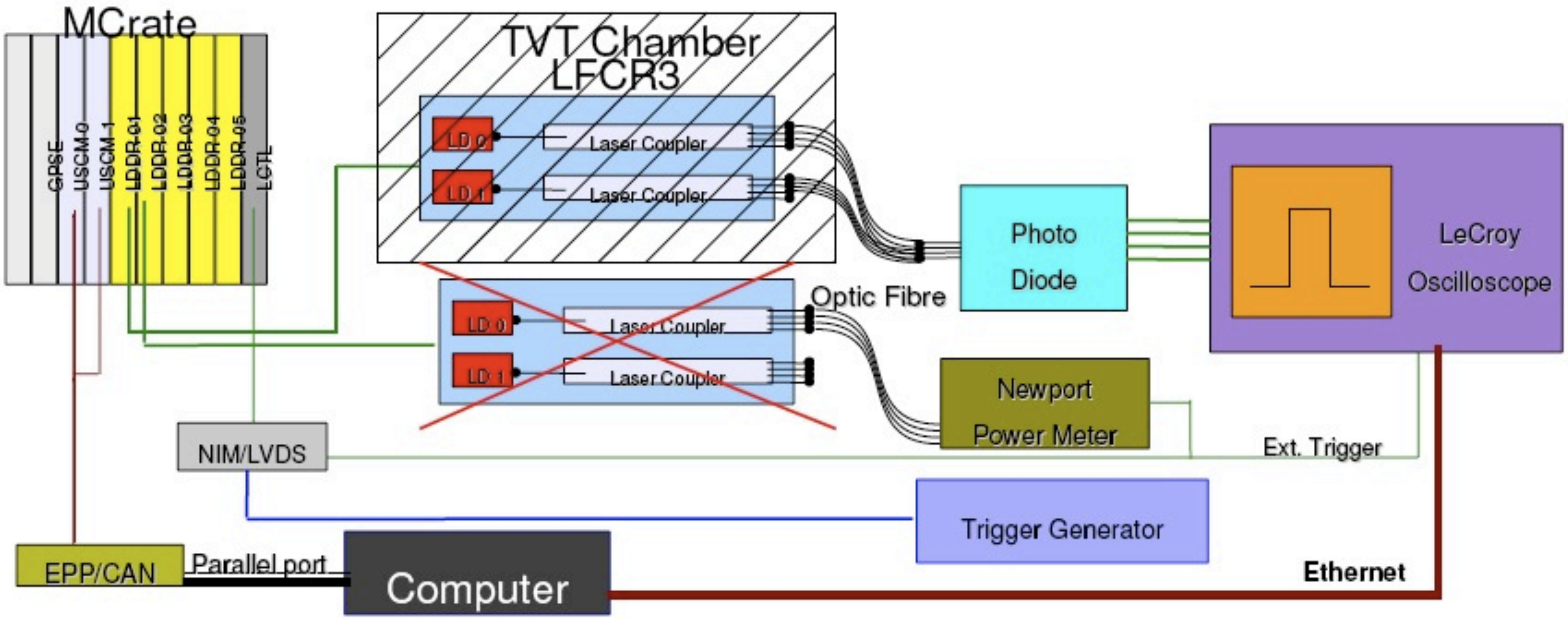
LFCR: Vibration Setup





LFCR Unit #3: Passive Vibration (6.8 g, X-Y-Z direction)

TVT Set-up



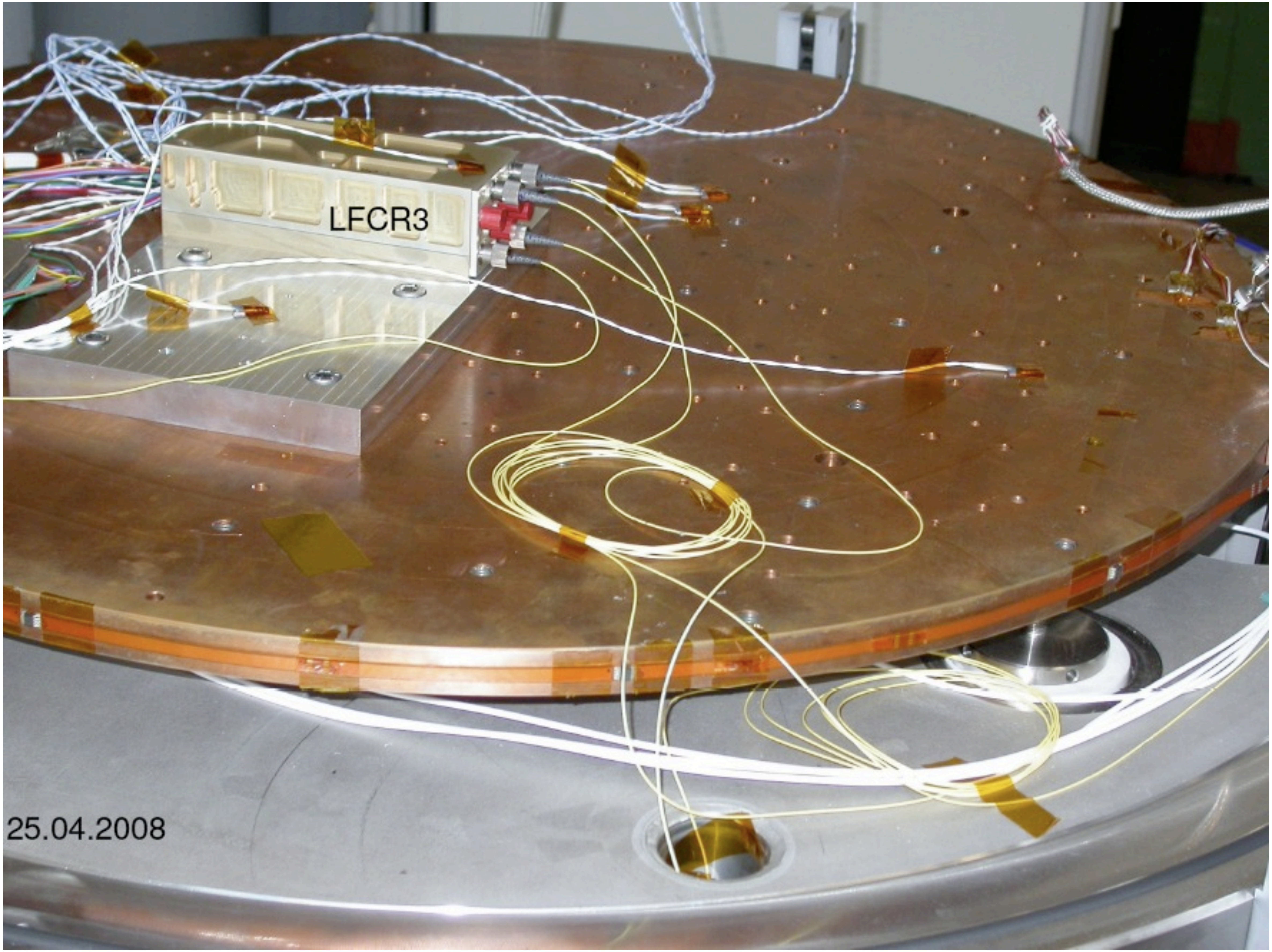
- IR(1082 nm) Laser Driver = M-Crate (LDDR)

  Control Range: Current = 20 ~ 60 mA, Width = 0.5 ~ 2 us

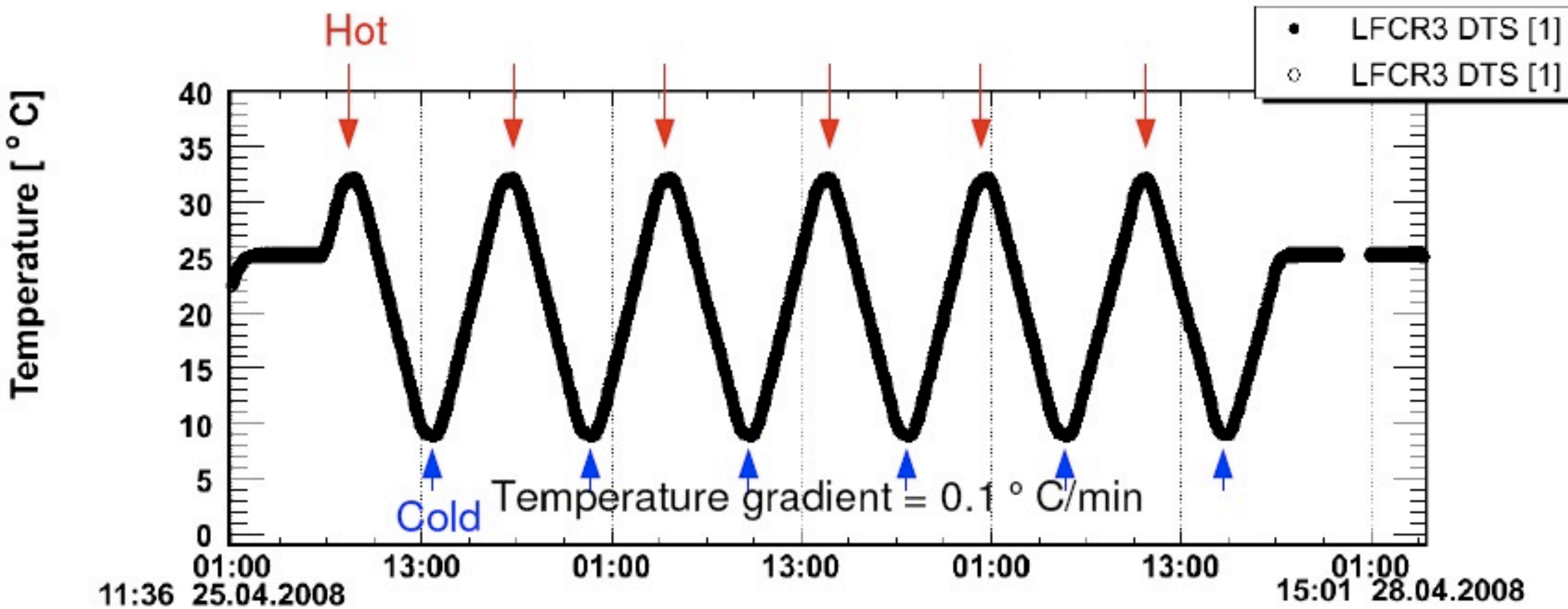
- Calibration with Photo Diode Box (5 x Ch. Amplifer)

  Inter-Calibration with Power Meter (Newport 1825C)

- Thermal Vacuum Test: +10 ~ +30 °C


LFCR3
25.04.2008

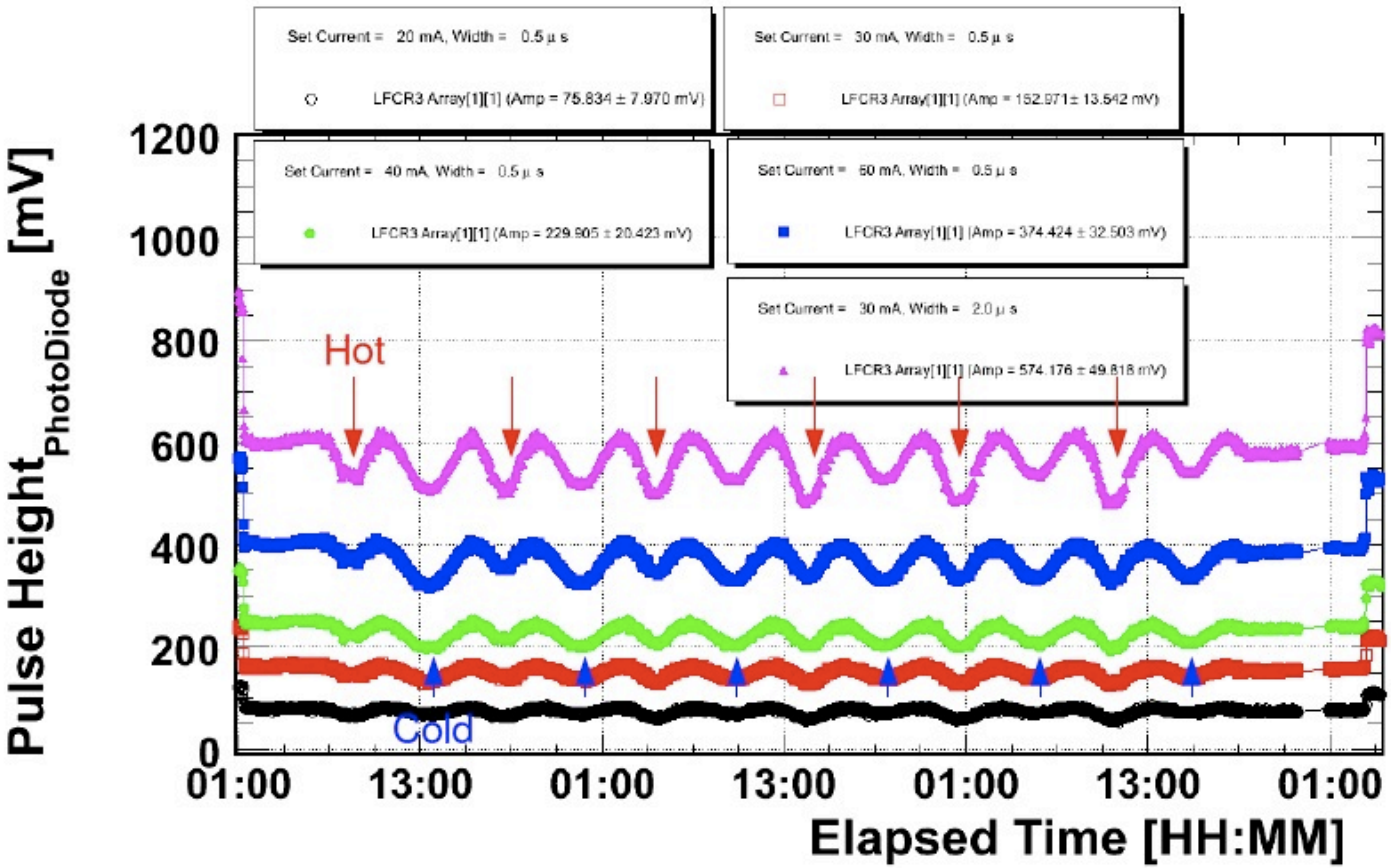
TVT : LFCR Unit 3 After Repair



Temperature Profile during TVT : +10 ~ +30 °C

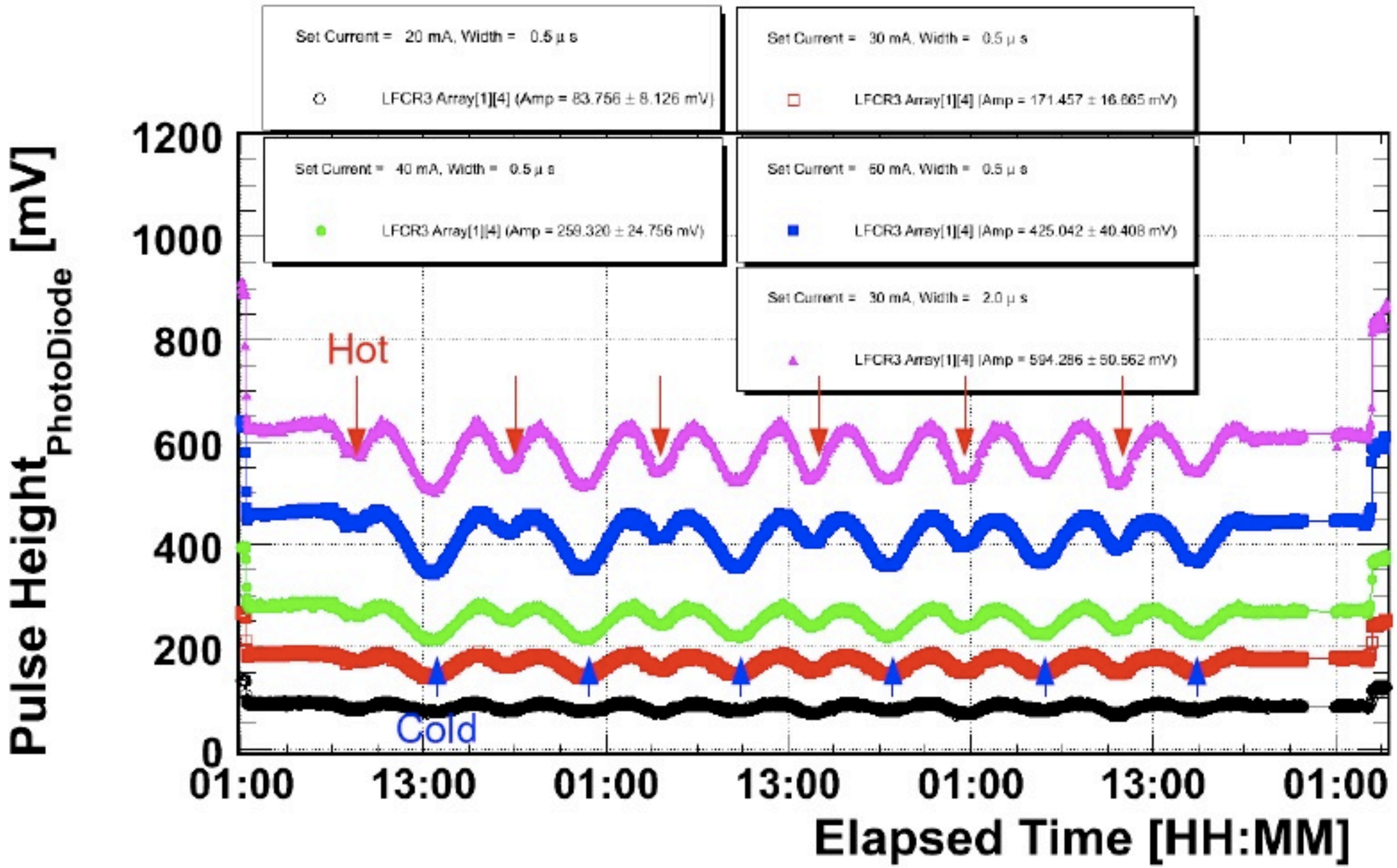
based on the TRD thermal model

LFCR3 Array 1.1   New Optic Splitter



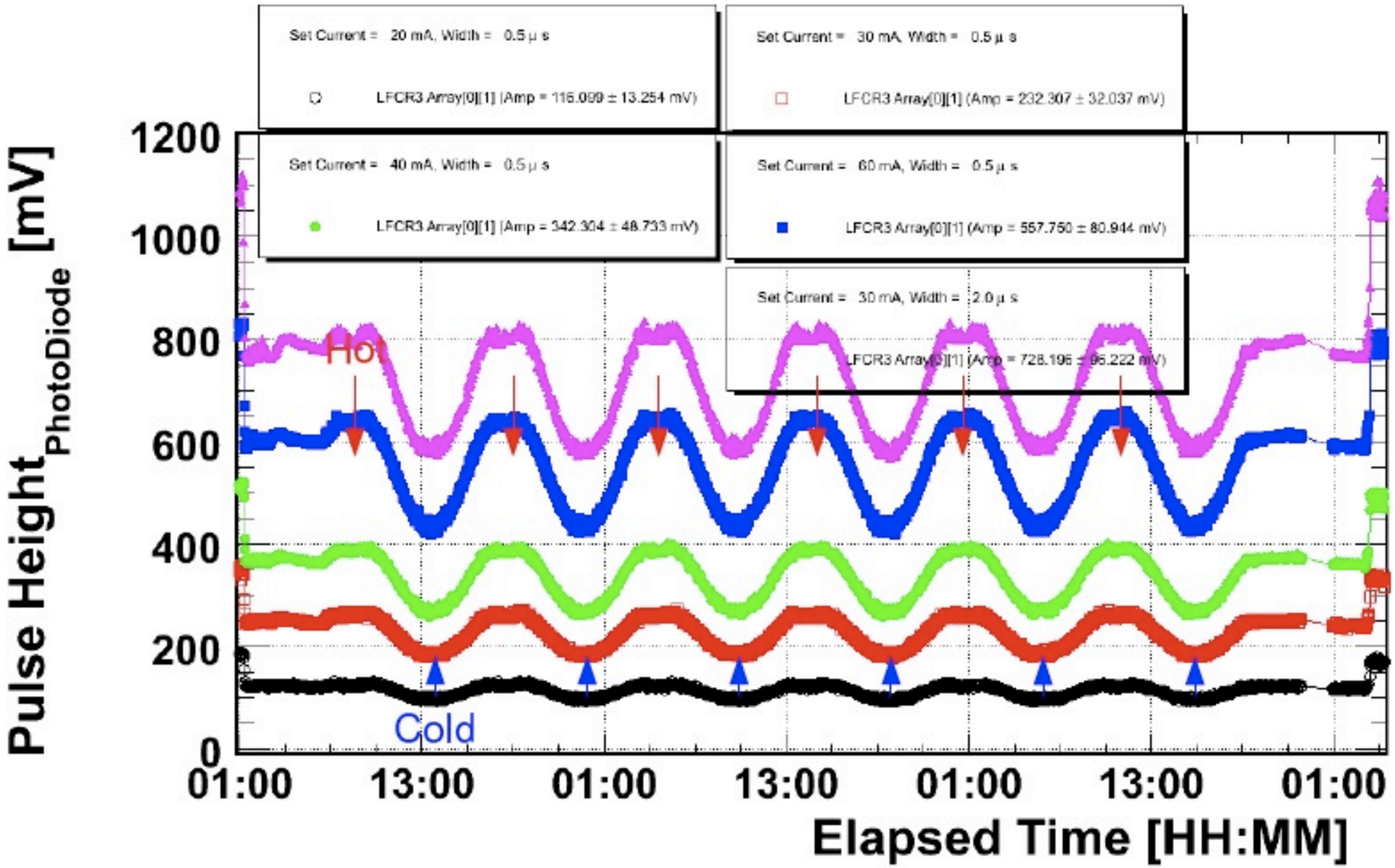
Test Condition: Current = [20,30,40,60 mA], pulse width = 0.5us, 2 us

LFCR3 Array 1.4   New Optic Splitter



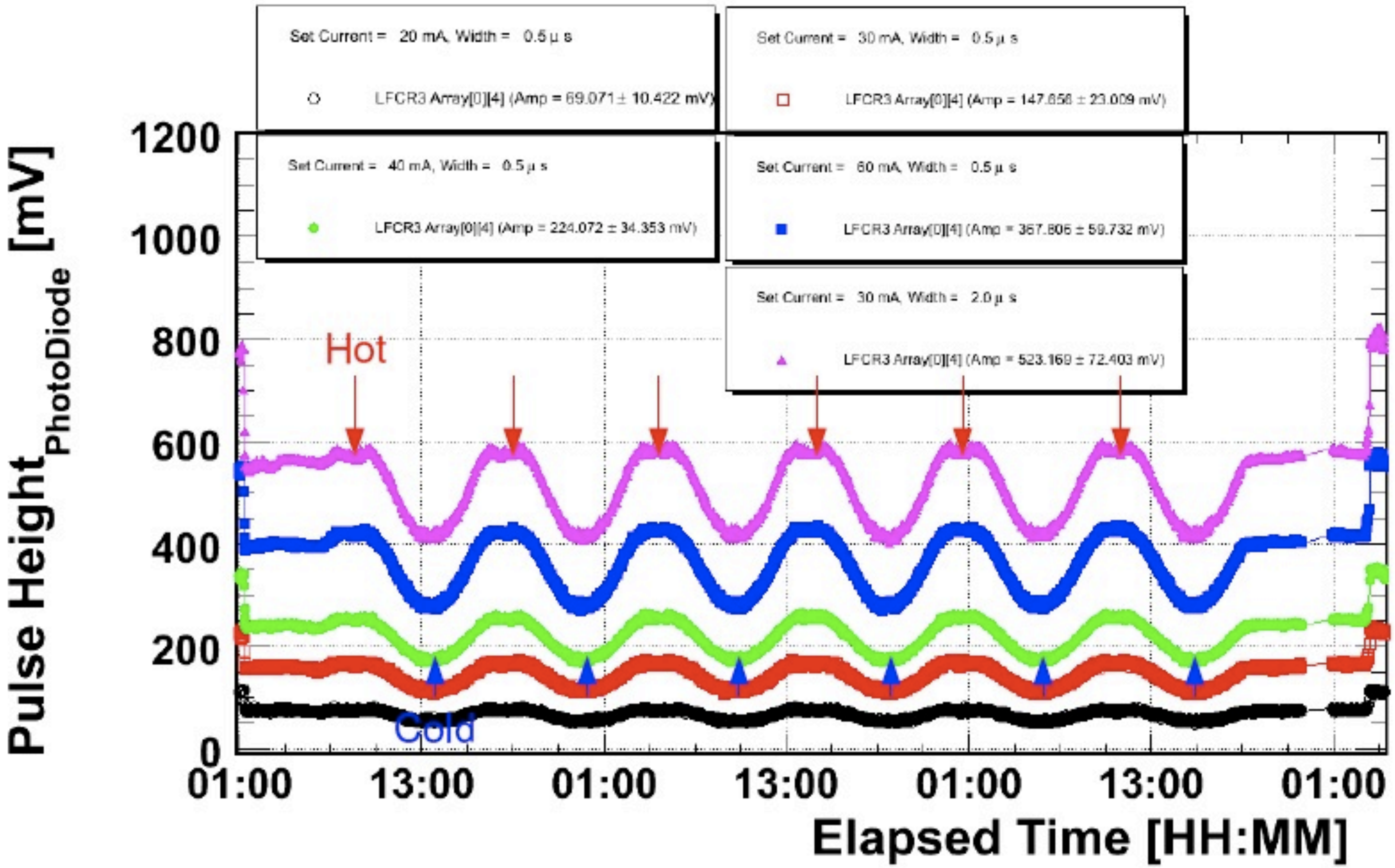
Test Condition: Current = [20,30,40,60 mA], pulse width = 0.5us, 2 us

LFCR3 Array 0.1



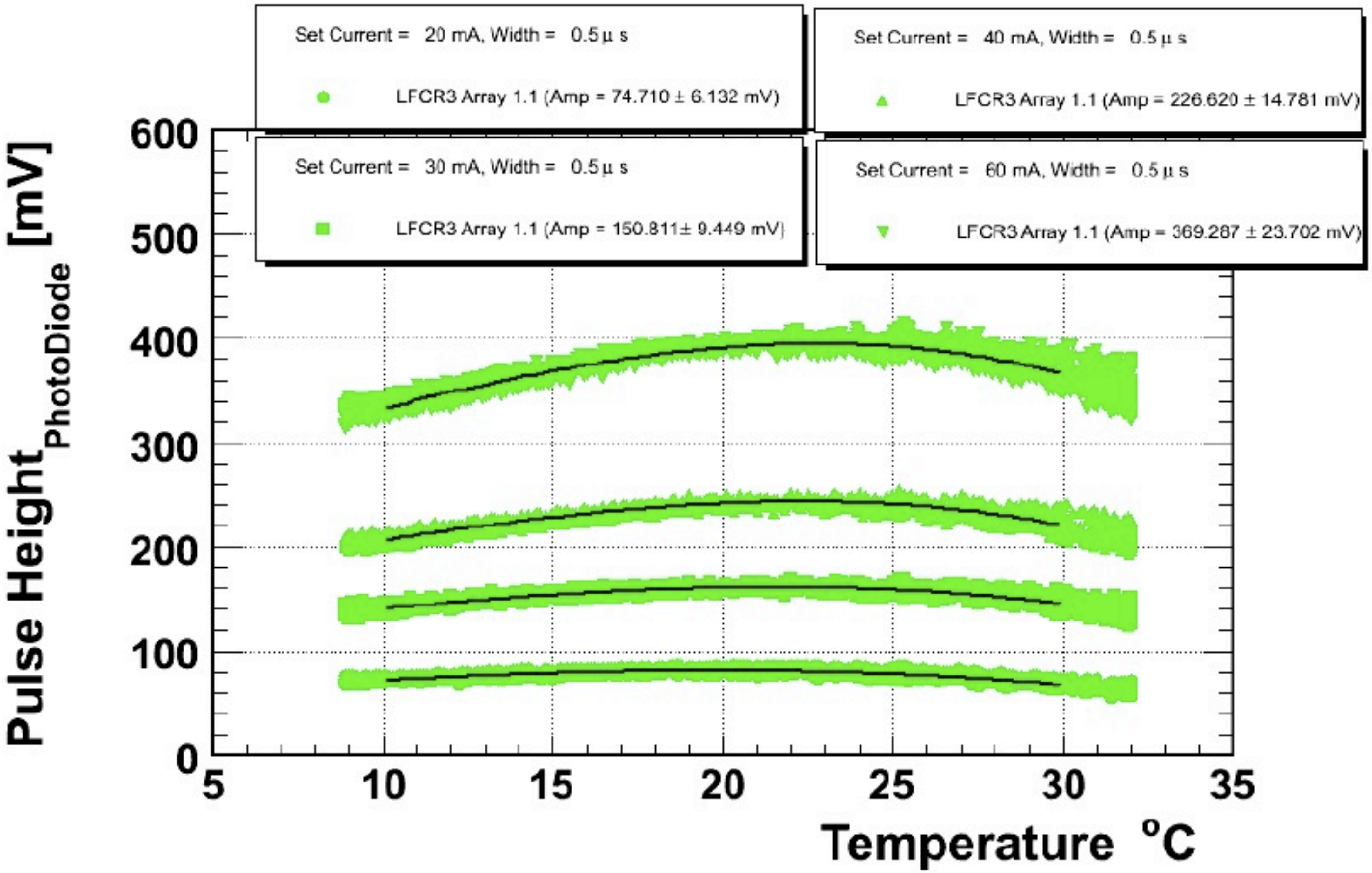
Test Condition: Current = [20,30,40,60 mA], pulse width = 0.5us, 2 us

LFCR3 Array 0.4

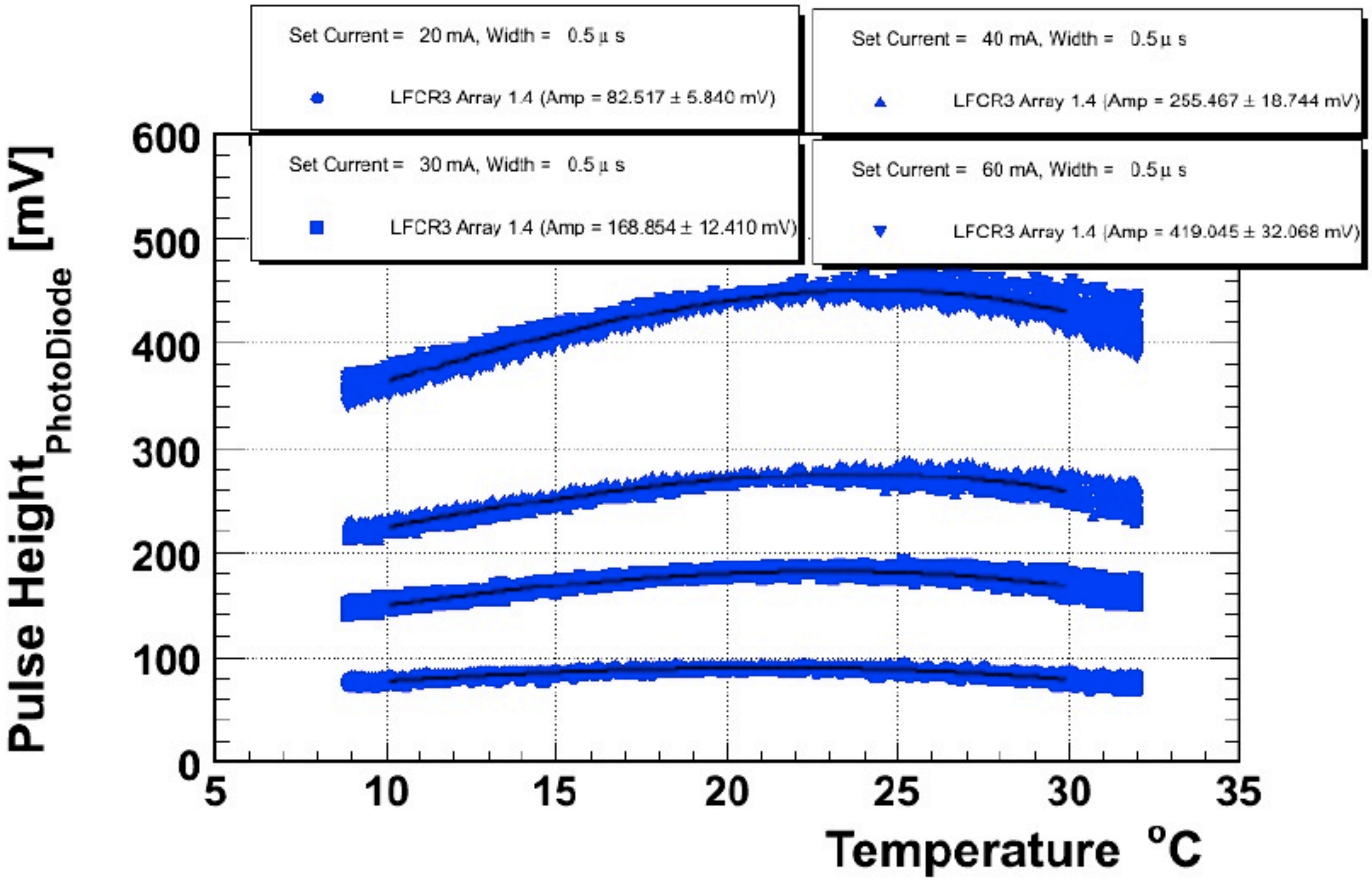


Test Condition: Current = [20,30,40,60 mA], pulse width = 0.5us, 2 us

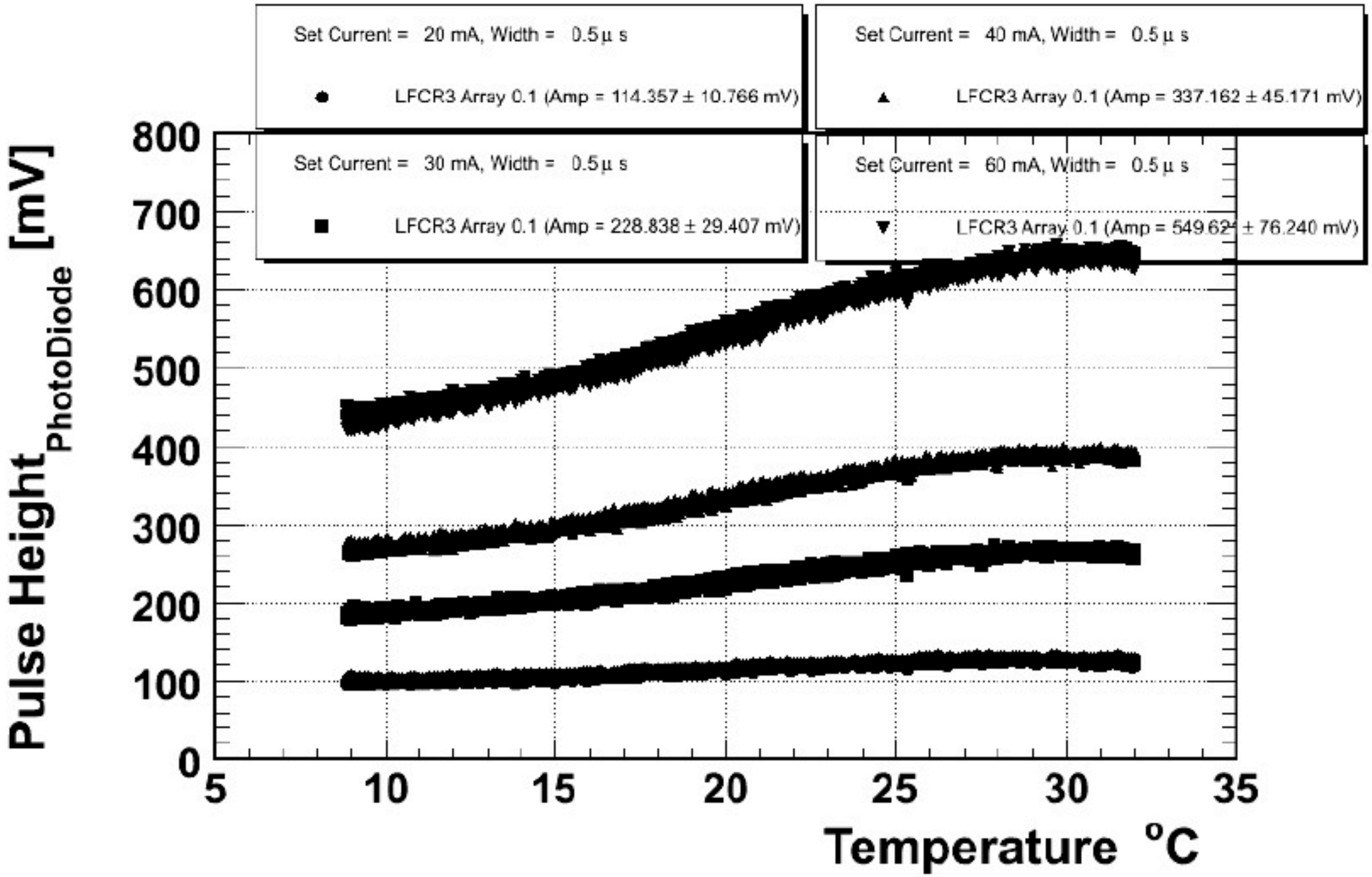
LFCR3 Array 1.1   New Optic Splitter



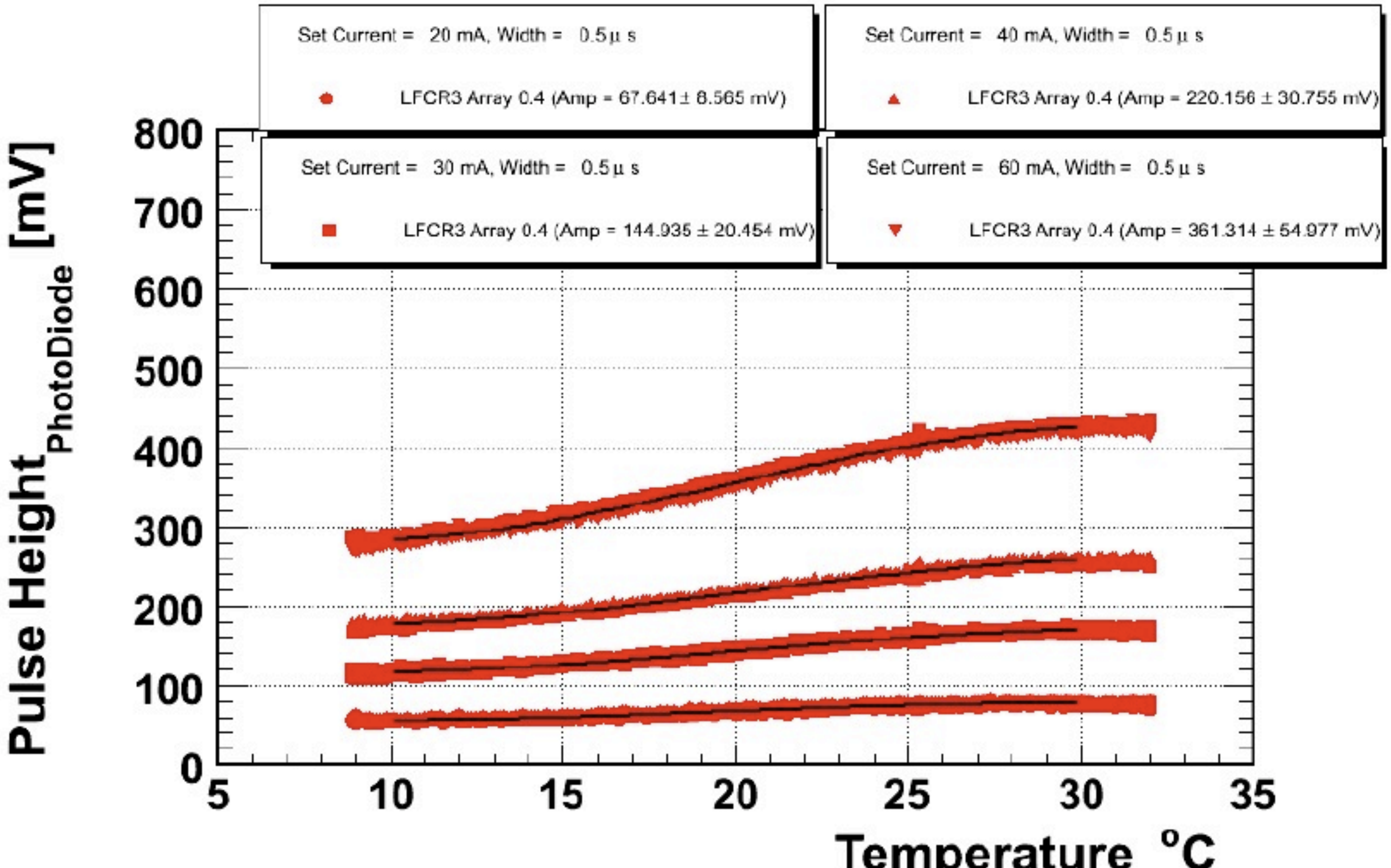
LFCR3 Array 1.4   New Optic Splitter



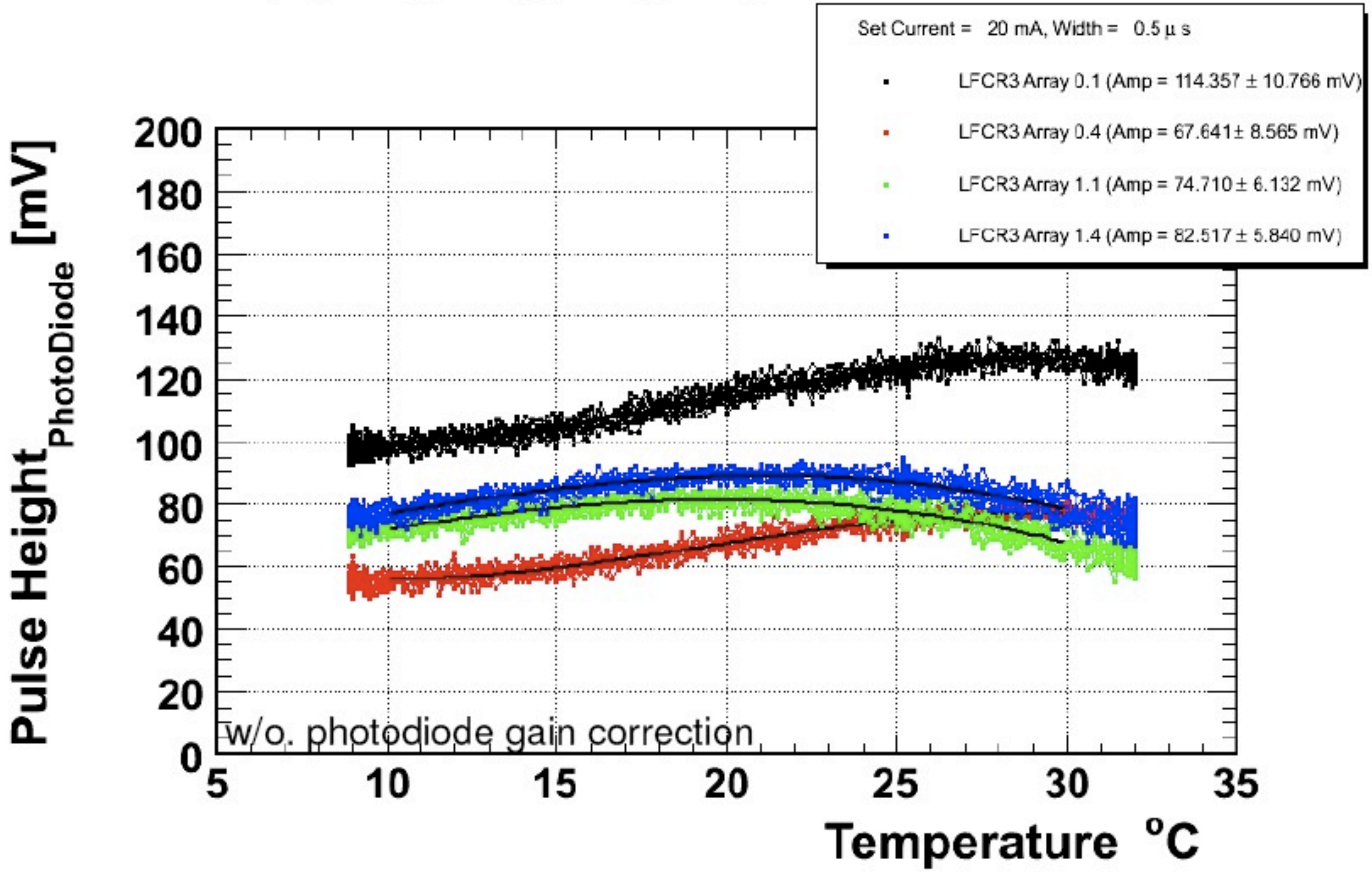
LFCR3 Array 0.1



LFCR3 Array 0.4

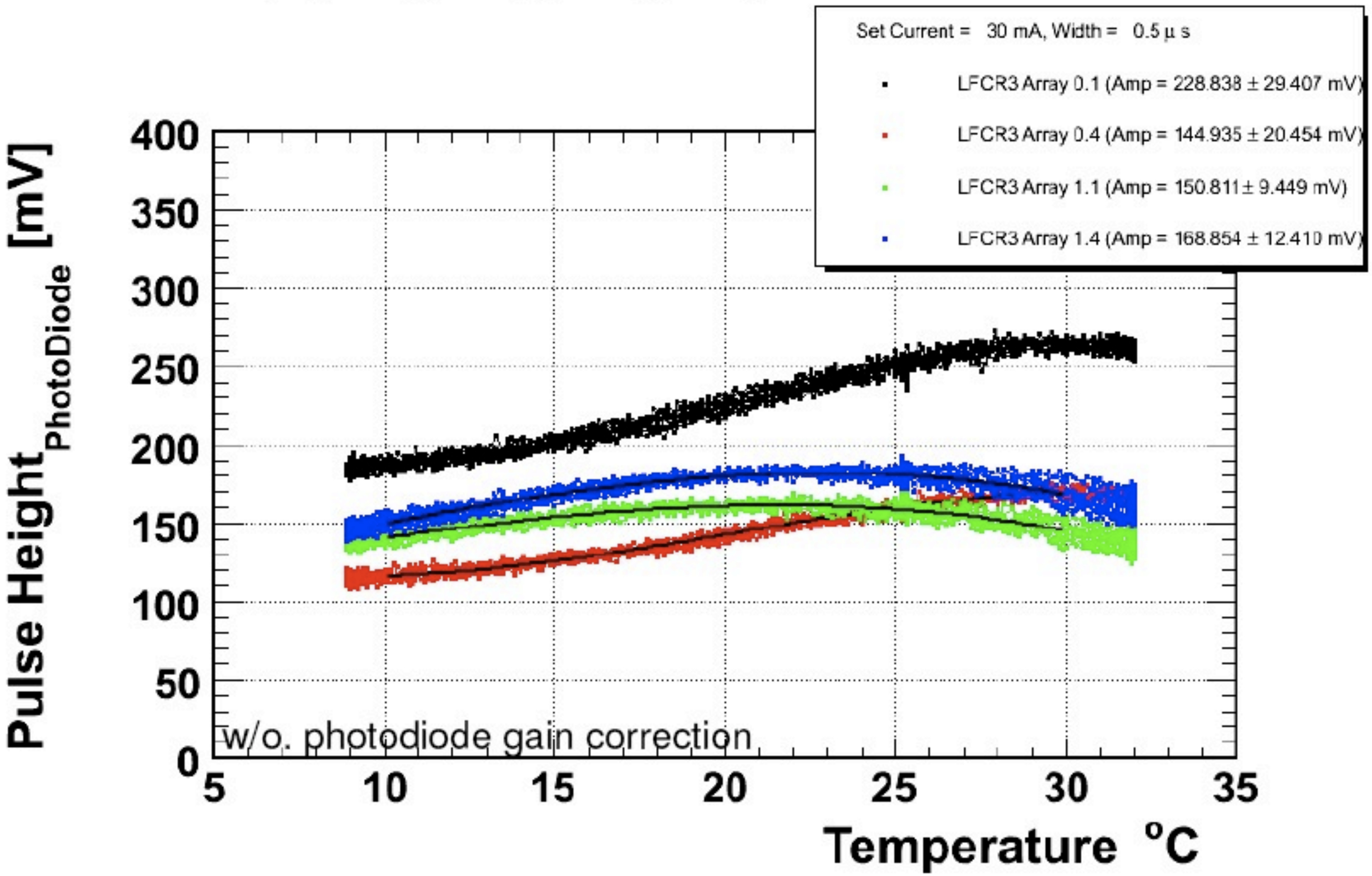


LFCR3 Array [0.1][0.4][1.1][1.4]



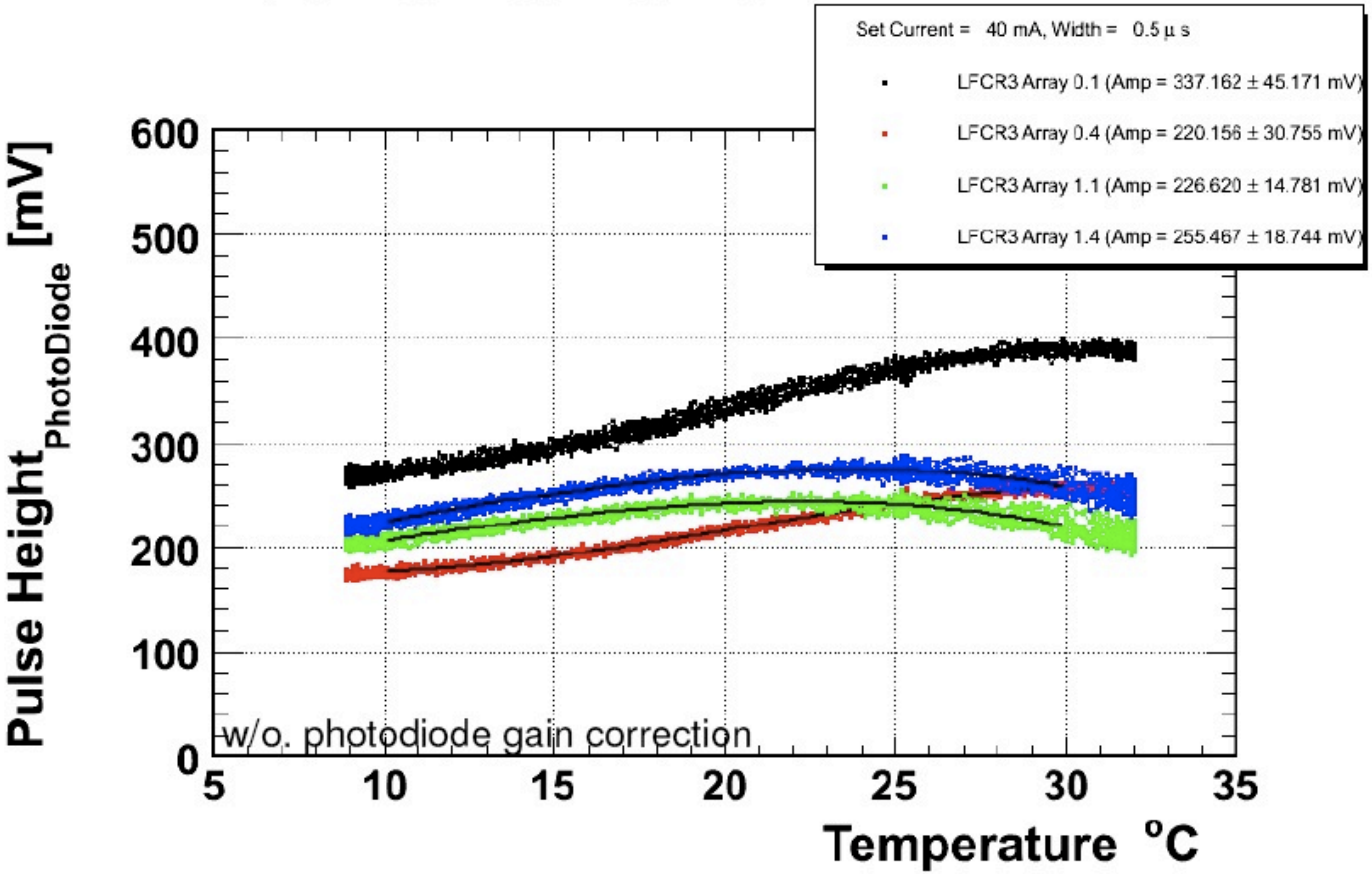
Current = **20 mA**, Pulse width = 0.5us

LFCR3 Array [0.1][0.4][1.1][1.4]



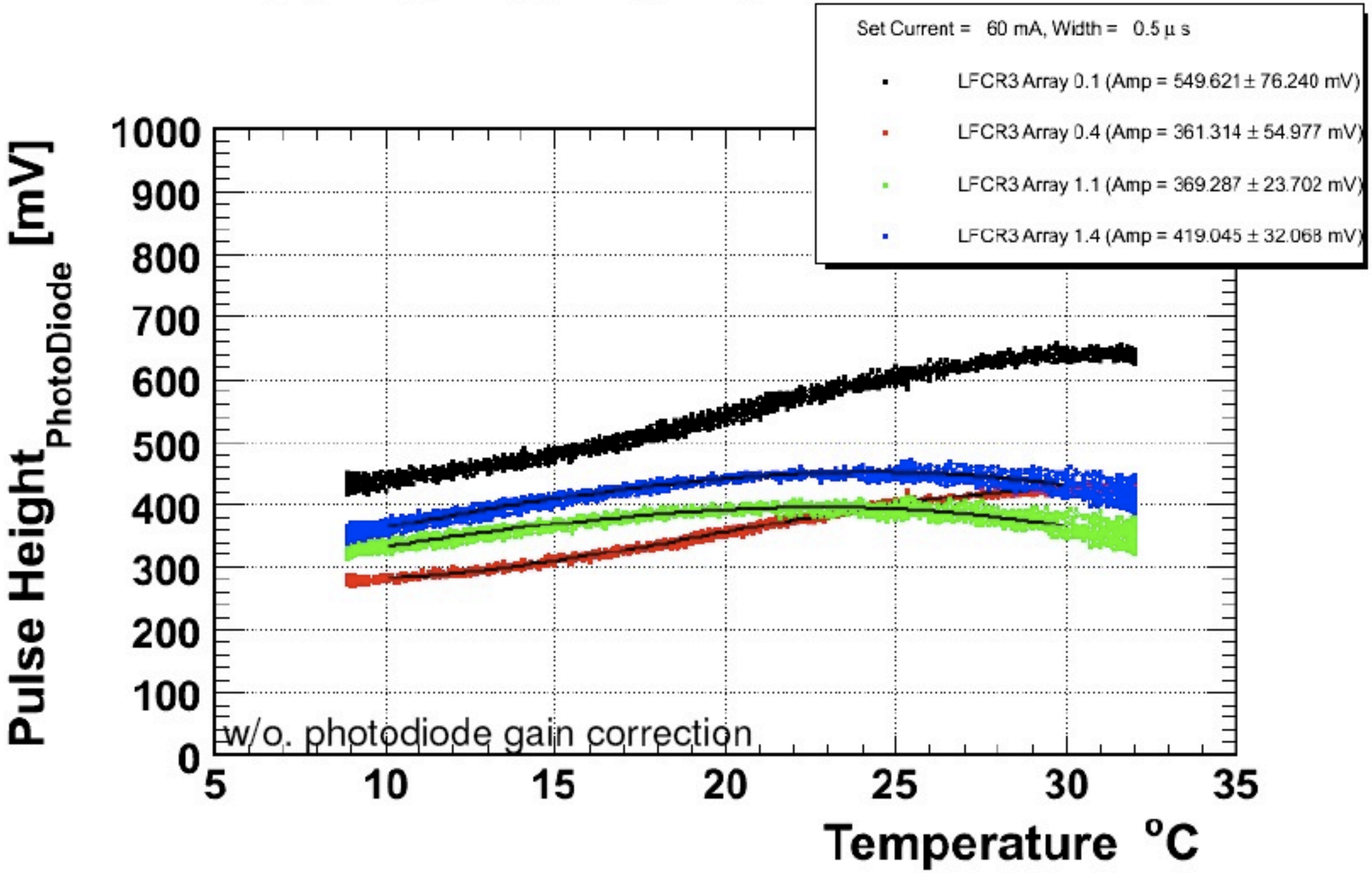
Current = **30 mA**, Pulse width = 0.5us

LFCR3 Array [0.1][0.4][1.1][1.4]



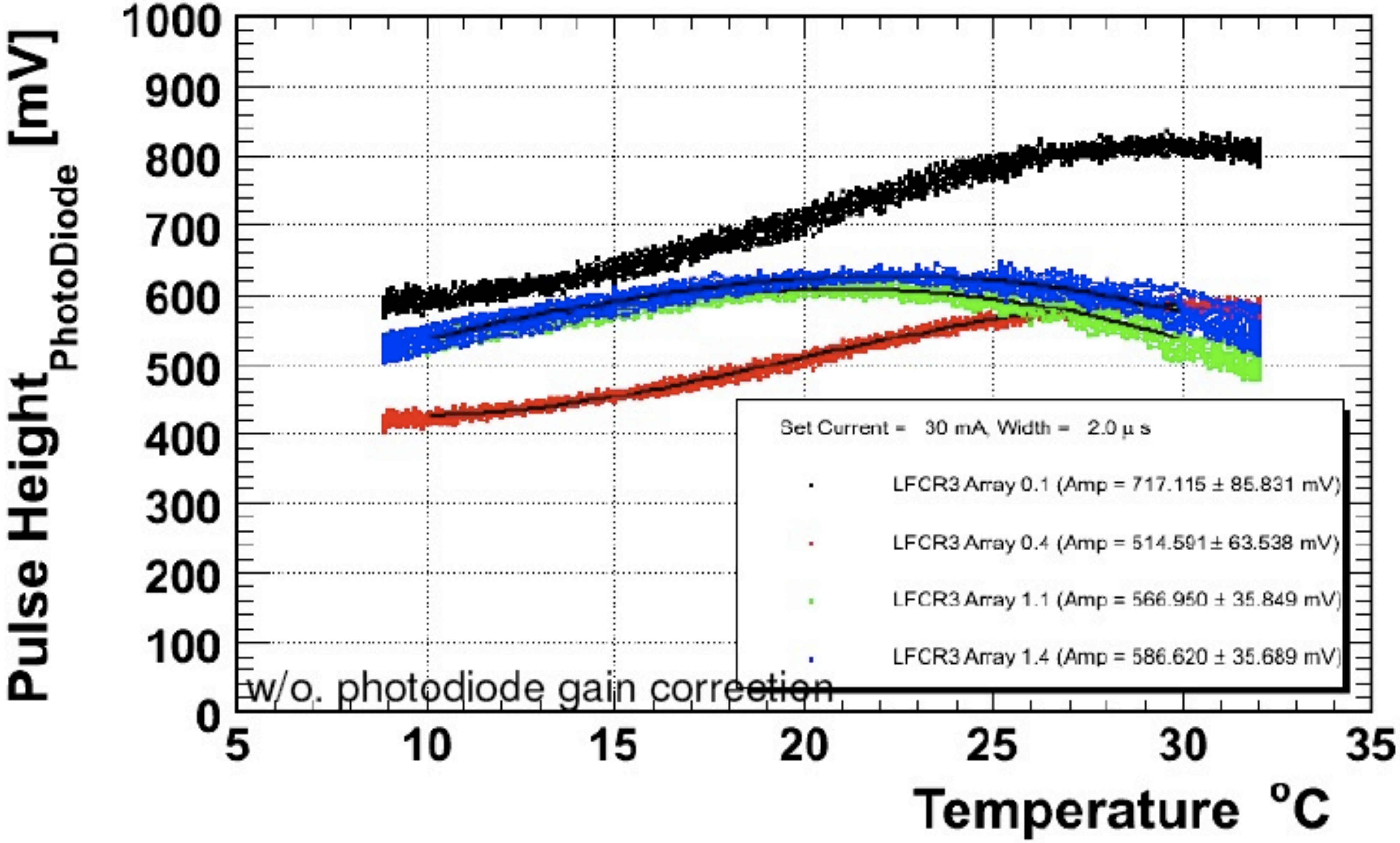
Current = **40 mA**, Pulse width = 0.5us

LFCR3 Array [0.1][0.4][1.1][1.4]

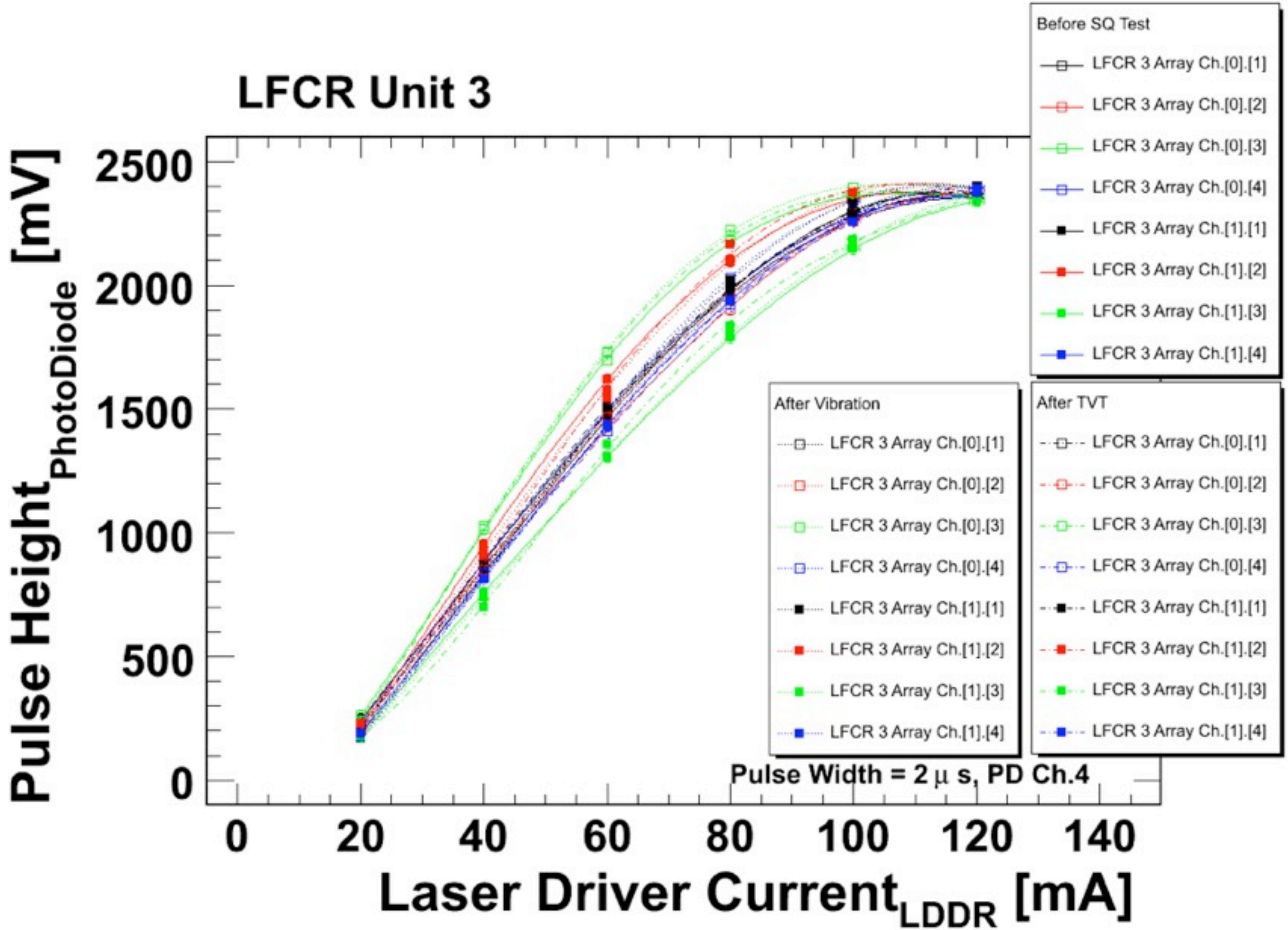


Current = **60 mA**, Pulse width = 0.5us

LFCR3 Array [0.1][0.4][1.1][1.4]



Current = **30 mA**, Pulse width = **2.0us**



No damage/degradation of LFCR Unit #3 from a series of SQT

The End